Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-07/0-5113-1		

4. Title and Subtitle	5. Report Date
ENHANCEMENTS TO THE ADVANCE WARNING OF END OF GREEN SYSTEM (AWEGS)	October 2006 Pub.: Dec. 2006
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Srinivasa R. Sunkari, Hassan A. Charara, Ricky T. Parker, and Trishul A. Palekar	Report 0-5113-1
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. Project 0-5113
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080	Technical Report: September 2004-August 2006
	14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Improving Intersection Safety and Operations Using Advance Warning of End of Green System (AWEGS)
URL: http://tti.tamu.edu/documents/0-5113-1.pdf

16. Abstract

The objective of this project was to make improvements to the Advance Warning of End of Green System (AWEGS). These improvements have enhanced the operation of AWEGS as well as have made the implementation of AWEGS much simpler. The enhancements include reducing false actuations, accounting for detector failures, detecting and treating queues, improving the visibility of the AWEGS sign, and making numerous modifications to the AWEGS interface. The improvements to AWEGS have made a significant improvement in the implementation of AWEGS at new locations.

These improvements were implemented at existing AWEGS sites and at a new location in College Station, Texas. However, the advance warning at the College Station location is higher than expected at times. This basically means that sometimes the controller is not gapping out after AWEGS predicted that it would. Analysis of the data has shown that this is primarily due to the high volumes on the arterial approaches at the College Station site. These results have illustrated that the volumes have an impact on the operation of AWEGS and should be considered in the selection of future AWEGS sites. From the data collected from all AWEGS locations, it appears that AWEGS would function very well when the average daily traffic (ADT) at the intersection is below 15,000 vehicles. Above those volumes, the advance warning times can be higher than expected. A higher advance warning is not harmful. However, if it happens frequently, it can give rise to some confusion in the motorists.

17. Key Words	18. Distribution Statement
Advance Warning Flashers, AWEGS, Advance Traffic Control Signs, W3-4 Signs, Advance Traffic Warning Devices, Traffic Actuated Control	No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	144	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

ENHANCEMENTS TO THE ADVANCE WARNING OF END OF GREEN SYSTEM (AWEGS)

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Texas Department of Transportation
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October 2006
Published December 2006

TEXAS TRANSPORTATION INSTITUTE
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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Srinivasa Sunkari, P.E. #87591. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

This research was conducted during a two-year study under a cooperative research program with TxDOT and FHWA. Michael Jedlicka of the TxDOT Bryan District was the project director. Tom Beeman of the Design Division was the project coordinator. Other TxDOT members of the project monitoring committee included Larry Colclasure, Carlos Ibarra, David Mitchell, Henry Wickes, and Wade Odell. Jeremy Johnson of the Texas Transportation Institute also contributed to the project.

TTI researchers specifically thank signal technicians from the Bryan District and the City of College Station for assisting us in the installation of the equipment for this project. This project would not have been implemented without their dedicated assistance.

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INTRODUCTION

In Texas, traffic signals are being installed more frequently at high-speed rural intersections. One of the major difficulties with traffic signal operation on high-speed approaches is related to the dilemma zone on high-speed approaches. The Texas Department of Transportation (TxDOT) has been actively sponsoring studies to develop systems that alleviate difficulties faced by motorists in dilemma zones. One of the systems developed by the Texas Transportation Institute (TTI) for TxDOT was Advance Warning of End of Green System (AWEGS) in Project 0-4260. AWEGS provides a warning of 5 to 6 seconds to the motorists about the end of green by flashing beacons on the intersection approach.

Background

The Texas Transportation Institute, with support from TxDOT, has developed a number of strategies to address the issue of improving safety at high-speed isolated signalized intersections. These include Detection Control-System (DC-S) (*1*), Platoon Identification Algorithm (PIA) (*2*), and AWEGS (*3*). These advance strategies improve the dilemma zone treatment at the intersections and enhance the signal operations. The objective of Project 0-5113 is to improve the operational strategies of AWEGS.

Motorists approaching a signalized intersection often face a dilemma of whether to stop or go at the onset of yellow (Figure 1). When the motorists are very far away from the intersection, they can probably stop at the onset of yellow. When they are very close to the intersection, motorists can probably continue and will enter the intersection before the termination of yellow. However problems occur when the motorists are in what is known as the "dilemma zone." This can occur even if proper guidelines are used to time the duration of yellow (*4*).

This dilemma becomes an acute problem for high-speed motorists and for truck drivers on the approaches to the intersections. TxDOT currently practices a detector design also known as Nader's guide (*5*) to minimize dilemma zone problems on high-speed approaches. Table 1 illustrates the detector placement according to Nader's guide (*5*). This detector design is however based on the 85th percentile approach speed and does not explicitly address very high-speed motorists and trucks. This causes an increase in red-light running (RLR) at these traffic signals, frequently resulting in accidents causing fatalities, severe injuries, and extensive property damage.

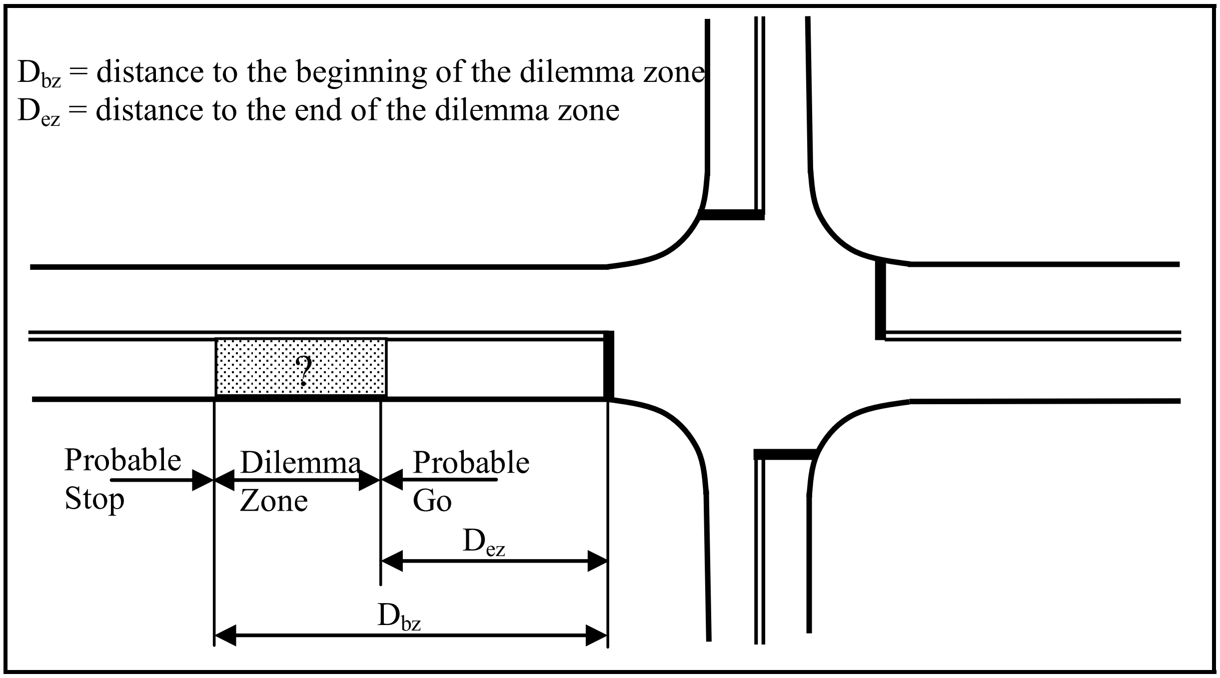


Figure 1. Dilemma Zone Problems for High-Speed Traffic Signals.

Table 1. Nader's Guide for Detector Installation for High-Speed Approaches.

Approach Speed, mph	Distance from Head of Detector to Stopline at Intersection, Feet			Stopline Area Detector [a]	Passage Gap, Seconds
	CDA[b] 1	CDA 2	CDA 3		
45	330	210	---	6′ x 40′	2.0
50	350	220	---	6′ x 40′	2.0
55	415	320	225	6′ x 40′	1.2
60	475	375	275	6′ x 40′	1.4
65	540	430	320	6′ x 40′	1.2
70	600	475	350	6′ x 40′	1.2

[a] Presence on red; then no call on green following first gap-out.
[b] Dilemma zone detectors

Some of the strategies devised by TTI like DC-S (*1*) and PIA (*2*) address the dilemma zone problems by actively controlling the operation of the traffic signal controller. These algorithms are always looking for windows of opportunity either to serve the motorists on the main street, or to terminate the main street phase when there is no traffic and serve the side street phase. AWEGS (*3*) on the other hand does not actively control the traffic signal controller. The algorithm is continually monitoring the traffic at the intersection and advance detectors on the high-speed approaches, and predicts the onset of yellow in the traffic signal controller. The algorithm then provides a warning to the motorists a few seconds before the onset of yellow by flashing beacons on a W3-4 sign located on the high-speed approaches. Figure 2 illustrates a W3-4 sign installed in Waco, Texas.

AWEGS was installed at two locations in Texas in a previous TxDOT project (0-4260). A summary of improvements due to AWEGS included a reduction in RLR of approximately 40 percent. The remainder of this section will address the background and development of advance warning flashers (AWF) in the United States and Canada and compare the differences between AWF and AWEGS.

Figure 2. AWEGS Sign in Waco, Texas.

Background of AWF

The decision process faced by motorists as the signal turns yellow leads to potential RLR, which has become a significant safety problem throughout North America. Crashes that occur under these circumstances tend to result in increased property damage and personal injury, oftentimes fatalities. Retting et al. (*6*) report that approximately 1 million collisions occur at signalized intersections in the United States each year. Of these collisions, it is estimated that at least 10 percent can be directly attributed to RLR. One of the methods currently under investigation and used sporadically throughout the United States and Canada is the installation of advance flashing beacons and/or other methods to provide advance warning to motorists of the end of the green signal phase, thus reducing or eliminating the dilemma faced by drivers. These installations have proved to be effective in several instances. Sayed et al. (*7*) have indicated that effective advance warning flasher implementation has the potential to minimize the number of vehicles in the "dilemma zone," which in turn could lead to an increase in safety in this zone and a reduction in accident frequency, which warrants evaluation.

Installation of Advance Warning Flashers

The installation of AWF devices can be traced as far back as 1968 in Alberta, Canada. Installations of this type have increased over the years to the point where the city of Calgary now has more than 30 installations within the city limits. Throughout the United States and Canada, AWF installations have been documented as taking on a number of different designs and practices. Bowman (*8*) has prepared a *Synthesis of Highway Practice* outlining the different advance warning devices that were not specifically identified in the *Manual on Uniform Traffic Control Devices (MUTCD)*. A wide variety of advance warning devices have been developed by transportation agencies to address unusual safety, operational, or environmental conditions that cannot be adequately addressed using standard warning devices found in the *MUTCD*. The synthesis presents the results of a literature review and state-of-the-practice survey conducted to provide useful information on advance warning devices that were not specified in the *MUTCD*. Both active and passive devices intended for long-term use were included in this analysis.

Bowman's work (*8*) identified 10 different text messages that were used by 10 different state agencies and five cities, comprising a total of 18 different devices due to the frequent use of the same text message but in different configurations. The results of this analysis indicate that the most widely used message was “Prepare to Stop When Flashing” (PTSWF), which was used in six different configurations by five different states and one city. Of the 15 agencies that used the devices contained in this subcategory, three states and one city used more than one device to warn of signal changes. Some 23 percent of the agencies responding to the questionnaire indicated that they used a device of this nature (*8*).

It can be concluded from the research done to date that there are many different types of installations for advance warning devices throughout the United States and Canada. These different installations make it difficult to compare one site to another because of the differences in design and installation. It is clear, however, that the PTSWF is the most common installation throughout the United States and is in practice in several different locations. The type of sign installation appears to have a definite impact on the effectiveness of the installation.

Safety Impacts

One of the main purposes for the consideration of the installation of advance warning devices has been to improve safety at high-speed signalized intersections. Several research projects have been undertaken over the years outlining the effects of AWF installation on safety. The main method for making a determination on safety has been in terms of accident reduction before and after installation. Agent and Pigman (*9*), Pant and Xei (*10*), Gibby et al. (*11*), Klugman et al. (*12*), and Sayed et al. (*7*) all found that intersections with advance warning appear to have lower left-turn, right-angle, and, in some instances, rear-end accidents.

Agent et al. (*9*) found that the use of an AWF should be limited to locations where either an existing or high potential accident problem exists, particularly a high percentage of angle accidents. Gibby et al. (*11*) provided more detail, indicating that high-speed approaches with AWFs had significantly lower total, left-turn, right-angle, and rear-end approach accident rates than those without AWFs. Gibby et al. also observed significantly lower ratios of nighttime accidents. The research performed by Klugman et al. (*12*) in Minnesota concluded that the use of AWF devices could be effective at reducing right-angle and rear-end accidents under certain situations but that the device does not automatically increase the safety of all intersections. Sayed et al. (*7*) provided the most detailed accident analysis, indicating that AWF intersections showed 10 percent fewer total accidents and 12 percent fewer severe accidents. Negligible reductions were observed with respect to rear-end accidents. Sayed continued his research, however, by indicating that the reduction was not found to be statistically significant at the 95 percent level of confidence.

Sayed et al. (*7*) also found a correlation between the accident frequency of AWF sites and the minor street traffic volumes. It was observed that when the minor street traffic volumes are low, the AWF sites have a higher frequency of accidents than non-AWF sites; however, with increasing minor street traffic volumes, the accident frequency for AWF-equipped intersections was found to be lower than at non-AWF sites. The specific results indicated that AWFs were effective at locations with a minor street annual average daily traffic (AADT) of 13,000 vehicles per day (vpd) or greater.

In addition to the comparison of accident reduction for intersections with AWF installations, Farraher et al. (*13*) collected data on the impact of red-light running and vehicle speeds through the intersection. Farraher et al. concluded that the installation of advance warning flashers provided a 29 percent reduction overall in red-light running, a 63 percent reduction in truck red-light running, and an 18.2 percent reduction in the speed of trucks through the survey intersection. Farraher commented that although the data indicate that advance warning flashers are effective at the site studied, the number of overall violators and their speeds has remained unacceptably high.

Another concern with AWF installation and safety is in relation to the potential for increased speeds as the advance warning device is activated. This is particularly true for the PTSWF and Flashing Symbolic Signal Ahead (FSSA) signs. Pant and Huang (*14*) and Pant and Xie (*10*) provide data from two separate studies in Ohio linking increased speeds at intersections with advance warning devices. Pant and Huang (*14*) found that an increase in speed at intersection approaches was common as the signal approached the red phase of the cycle. This was particularly true for tangent approaches and less of a concern for curved approaches where limited sight distance existed. Pant and Huang concluded that the use of advance warning devices, particularly PTSWF and FSSA signs, should be discouraged since they were found to encourage high speeds under some conditions. Pant and Xie (*10*) performed a follow-up study to this research and found once again that when flashers were off and the signal indication was clear, drivers faced with a PTSWF or FSSA sign generally increased their speeds in an attempt "to beat the light." Once again this was particularly true on tangent approaches, and as such advance warning devices were discouraged from installation, particularly on tangent sections.

The research performed to date indicates that intersections with AWFs have consistently provided lower overall accident rates and fewer severe accidents than intersections without the devices. These reductions, however, have not been shown to be statistically significant. The drawbacks for safety, however, are in the documented increase in red-light running after the start of red and the increase in speeds approaching the intersection under certain conditions. These impacts must be weighed in choosing sites for advance warning installations.

The literature review so far illustrates the benefits of AWF, their applicability, and their potential limitations. These applications or deployments, however, did not have an official guideline for the selection and installation of AWF. The 2000 *MUTCD* (*15*) was the first document that explicitly defined the use and installation of the AWF. Section 2C.26 of the *MUTCD* (*15*) details the use of the signs required for the advance warning for end of green. During the implementation of AWEGS in Project 0-4260, TxDOT's new *Sign Crew Field Book* (*16*) and the relevant *MUTCD* sections (*15*) were consulted for official design requirements and guidance.

AWEGS

There was a significant difference in the functionality of AWF and AWEGS (*3*). Like the AWF deployments, even AWEGS used a W3-4 sign located upstream of the intersection. This W3-4 sign had beacons that would start flashing a few seconds before the onset of yellow. However, this is where the similarities ended. AWFs have typically been used at traffic signals that are operating in a fixed time mode. When operating in a fixed time mode, it is fairly simple and straightforward to start flashing the beacons on W3-4 signs at a certain number of seconds before the onset of yellow. However, operating traffic signals having high-speed approaches in a fixed time operation is dangerous because no dilemma zone protection is provided inherently by the traffic signal. Motorists are completely dependant on the AWF for dilemma zone protection. There were a few AWF applications deployed at intersections operating in fully actuated mode. However in these cases, a trailing green overlap was used to provide the advance warning before the end of green. Figure 3 illustrates the trailing green overlap functionality.

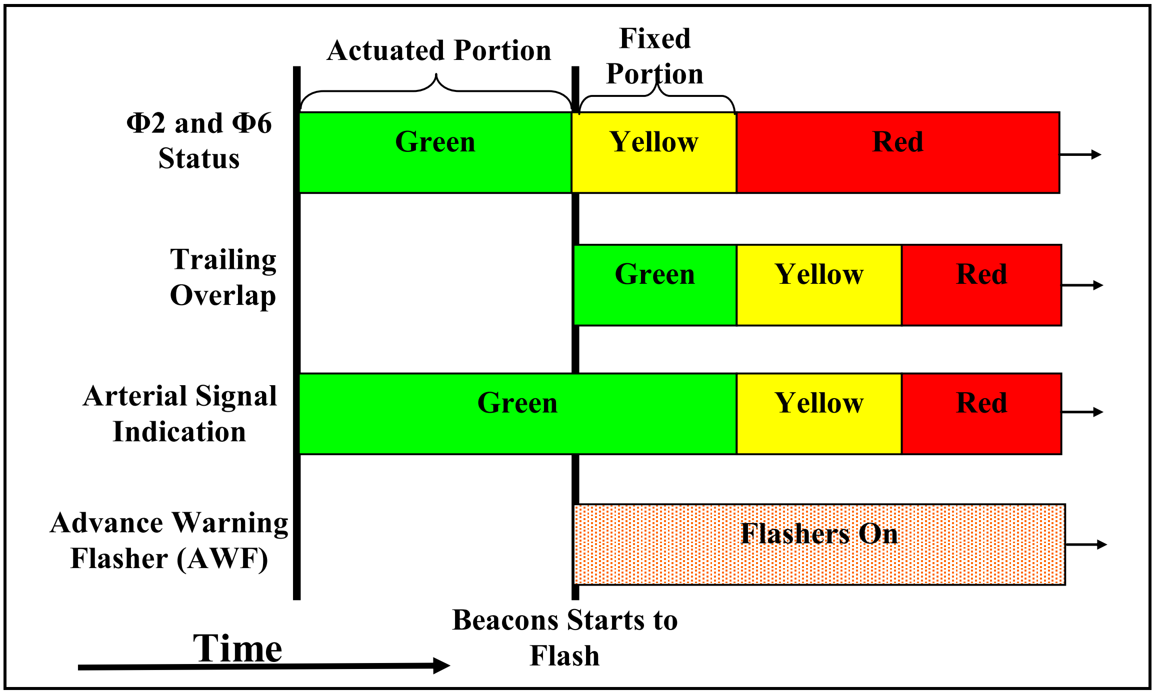


Figure 3. Trailing Overlap in AWF.

As seen in Figure 3, beacons will start flashing at the onset of the trailing overlap. Since the duration of the green in a trailing overlap is a fixed interval, the period between the time the beacons start flashing and the onset of yellow indication is always constant. This means that the phase indication ends in a fixed time mode even though the phase is actuated for most of its duration. This similarly results in no dilemma zone protection being provided on these approaches by the signal operation. As mentioned earlier TxDOT uses a detector layout for high-speed approaches that provides dilemma zone protection for a large segment of the traffic. Hence, operating AWFs by eliminating the existing dilemma zone protection was not an option.

AWEGS is designed to operate at traffic signals operating in fully actuated mode while maintaining and enhancing the existing dilemma zone protection. In brief, AWEGS predicts the onset of yellow by monitoring the actuations on all the intersection detectors and the advance detectors on the high-speed approach, and monitoring the signal controller status.

The algorithm uses the actuations on the advance detectors to estimate the vehicle speed, classify the vehicle type, and calculate the beginning and the ending of the dilemma zone of each and every vehicle. This includes trucks, which have different dilemma zone limits. One of AWEGS's objectives is to ensure that no vehicle on the high-speed approach is caught in its dilemma zones at the onset of yellow. Based on the estimate of the speed of the vehicle at the advance detectors, AWEGS continuously monitors the location of the vehicle in real time before the vehicle gets onto TxDOT's dilemma zone detectors. Once the vehicle is on the dilemma zone detectors, the controller is extending the phase and safely clearing the vehicle through the intersection. TTI provided recommended passage times to be used with the configuration of the TxDOT dilemma zone detectors to ensure safe dilemma zone detector operation. In the rare case that the vehicle is in its dilemma zone (before getting onto the dilemma zone detectors) when a vehicle arrives on a conflicting phase, AWEGS calculates and places a phase hold of the duration necessary to get the vehicle onto TxDOT's dilemma zone detectors. This phase hold is thus variable and was found to range between 1.2 to 2.4 seconds depending on vehicle speed and location of the high-speed vehicle when a vehicle arrives on the conflicting phase. Studies have indicated that this phase hold is placed between 10 to 20 times a day. A phase hold ensures that no vehicle is ever caught in its dilemma zone and AWEGS's influence on the operation of the controller is minimal.

Based on the activity on the detectors during conflicting phases and the location of vehicles on the high-speed approaches, AWEGS initiates the flashing of the beacons on the W3-4 signs, warning the motorists about the onset of yellow. AWEGS was installed at the intersection of SH 6 and FM 185 in Waco in November 2002 and at the intersection of US 290 and FM 577 in Brenham in June 2003. The algorithm has been operating satisfactorily at both locations.

Improvements Identified in Future Projects

Implementation of AWEGS in College Station, however, faced some challenges. Since AWEGS's functionality was heavily dependant on the information being fed by the intersection detectors, it was critical that the vehicle actuations were accurate. However due to the geometric conditions and motorist driving habits, there were a fair amount of false actuations. AWEGS, however, responded to these false actuations, which resulted in some inefficiency in overall intersection operations. Some efforts were made to reduce these false actuations, but the problems persisted.

Trucks benefit significantly from AWEGS. However, AWEGS still treats trucks as vehicles with different dilemma zone limits. The algorithm does not provide any priority to trucks. At locations with a large number of trucks, it may be desirable to provide some priority.

However, this priority should not come at the expense of efficient intersection operations. Hence, it was necessary to study the impacts of AWEGS on trucks and the impact of any potential truck priority module on intersection operations.

Another unique aspect of AWEGS compared to other advance intersection control strategies like DC-S (*1*) or PIA (*2*) is that AWEGS's functionality involves an active driver response. Upon the activation of the beacons on the W3-4 sign, motorists need to comprehend and comply with the sign. In Project 0-5113, researchers developed alternative options for the sign structure and flashing operation. An overhead sign was designed, and a new kind of flash was developed to improve the attention value of the sign.

Because AWEGS is a fully functional algorithm operating in the field, some failsafe mechanisms had to be developed. These included failure of the advance detectors as well as dilemma zone detectors. Failure of detectors can have a very adverse impact on the algorithm operations.

AWEGS IMPROVEMENTS

AWEGSs in Waco and Brenham have been successfully operating since their deployment in 2002 and 2003, respectively. A number of challenges have however been identified. The following sections describe these challenges in greater detail and identify potential improvements to overcome these challenges.

False Detections

False flashing of the advance beacons in AWEGS occurs because of temporary legitimate actuations or false actuations on detectors belonging to phases that conflict with the main-street phases. The temporary legitimate actuations occur in the case of right-turning vehicles from shared lanes on a side street, or arterial left-turning vehicles in the case of protected-permitted operations. On the other hand, false actuations occur when arterial left-turning vehicles actuate side-street detectors or when left-turning vehicles from a side street actuate arterial left detectors. AWEGS, in trying to predict the end of the main-street phases and provide advance warning of 5 to 6 seconds to motorists, might make the prediction, if conditions are right, that one or both of the main-street phases are going to end, due to the conflicting calls on side-street or arterial lefts. AWEGS then starts flashing the advance beacons to warn approaching traffic. However, the legitimate or false calls, on detectors belonging to phases conflicting with arterial phases, will usually disappear a few seconds later. AWEGS realizes that its prediction of the main-street phases ending was wrong, and it needs to stop flashing the advance beacons. AWEGS will continue flashing the advance beacons until it determines that conditions are safe for turning them off without impacting approaching traffic on the main street. AWEGS will also create a record in the ".FFlash" data logging file if the logging of false actuations was activated. The record will indicate whether it was a false flash due to side-street or arterial left-turn detector false actuations.

In order to minimize the number of times AWEGS might start flashing the beacons due to false actuations on the detector, TTI researchers tried several techniques, including:

- delay on detectors belonging to conflicting phases,
- directional video detection, and
- two stop-bar detectors instead of one on conflicting side-street and arterial left-turn phases.

Detector Delay

TTI researchers recommend a delay of 1 to 5 seconds on the arterial left-turn phases and side-street phases in the controller. This delay is programmed in the signal controller and not on the detector amplifier. The delay minimizes the occurrences of the traffic signal controller and AWEGS responding unnecessarily to false calls on side-street detectors by arterial left-turning vehicles, false calls on arterial left turns by side-street vehicles turning left, or legitimate side-street right-turning vehicles and arterial left-turning vehicles during protected-permitted operations.

Directional Video Detection

TTI researchers envisioned using the directional detection feature in some video imaging vehicle detection systems to eliminate false detection on side-street and arterial left-turn detectors since in both cases detectors are falsely actuated due to vehicles moving in the wrong direction of traffic.

Two Stop-Bar Detectors

As part of the AWEGS installation at the intersection of FM 2818 and George Bush Drive in College Station, Texas, TTI researchers installed two Sensys wireless detectors at the westbound side-street stop bar. The purpose of installing two detectors instead of one was to simulate directional detection and evaluate the detectors' effectiveness in preventing false side-street stop-bar detector actuations due to arterial left-turning vehicles. The idea is to compare the order of the actuations of the two Sensys detectors and decide if the actuations were due to a vehicle driving in the proper direction and activating the detectors in the proper order (i.e., Sensys detector 1 and then Sensys detector 2) or due to a left-turning vehicle actuating the detectors in the wrong order (i.e., Sensys detector 2 and then Sensys detector 1).

Improving AWEGS Sign Attention Value

AWEGS installations were deployed using the typical W3-4 roadside-mounted signs. The Waco installation consisted of a single W3-4 sign on the intersection approach, and the Brenham installation consisted of two W3-4 signs on either side of the intersection approach. Figure 4 illustrates these two sign configurations.

a. Waco b. Brenham

Figure 4. Roadside-Mounted W3-4 Signs.

There are numerous other configurations of the AWF signs being used across the United States and in Canada. Some of these include an overhead sign configuration. AWEGS's effectiveness depends on motorists noticing the W3-4 sign and flashing beacons, understanding the sign, and responding to it. The W3-4 sign has to stand out from among the other signs due to its dynamic nature of operation. However, as can be seen in Figure 4, frequently there is a lot of sign clutter on the intersection approaches. This clutter can make it difficult for motorists to see the W3-4 sign. This situation is further exacerbated if there are some flashers on other signs near the intersection. The flashing beacons on the W3-4 sign may not catch the motorists' attention since they may see too many beacons flashing near the intersection area.

To study this issue a pair of sign and safety experts from TTI were taken to the Brenham AWEGS site. The AWEGS operation was studied by making multiple runs on the approaches to the intersection. The experts concurred with the concern of sign clutter on the approach and strongly supported researchers' objective to design and install an overhead sign. Such a sign would significantly stand out from the other signs and improve the sign visibility. The experts also suggested using a different type of flashing operation in the beacons to make them different from the other flashing beacons at the intersection.

Overhead Sign Design

TTI researchers and TxDOT engineers took existing design specifications for the W3-4 signs to design the overhead sign. The critical specifications are:

- Use 8-inch letters for the "Be Prepared to Stop" text.
- Use 6-inch letters for the "When Flashing" text.
- Use a single sign for both the texts.
- Use 12-inch lens for the light-emitting diodes (LEDs).

The existing W3-4 signs used black letters on a yellow background. However, during the design of the overhead sign, TxDOT had begun using a fluorescent yellow background for warning signs. Fluorescent yellow significantly improves the visibility of the sign. Visibility increases significantly during nighttime. Hence, a fluorescent yellow background was adopted for the design of the overhead sign. Figure 5 illustrates the layout of the overhead sign.

The overhead sign is characterized by the following:

- 4 feet high by 8 feet wide,
- 8-inch letter height (Type D) for "Be Prepared to Stop,"
- 6-inch letter height (Type D) for "When Flashing,"
- black letters on a fluorescent yellow background, and
- 12-inch LED beacons on either side of the sign.

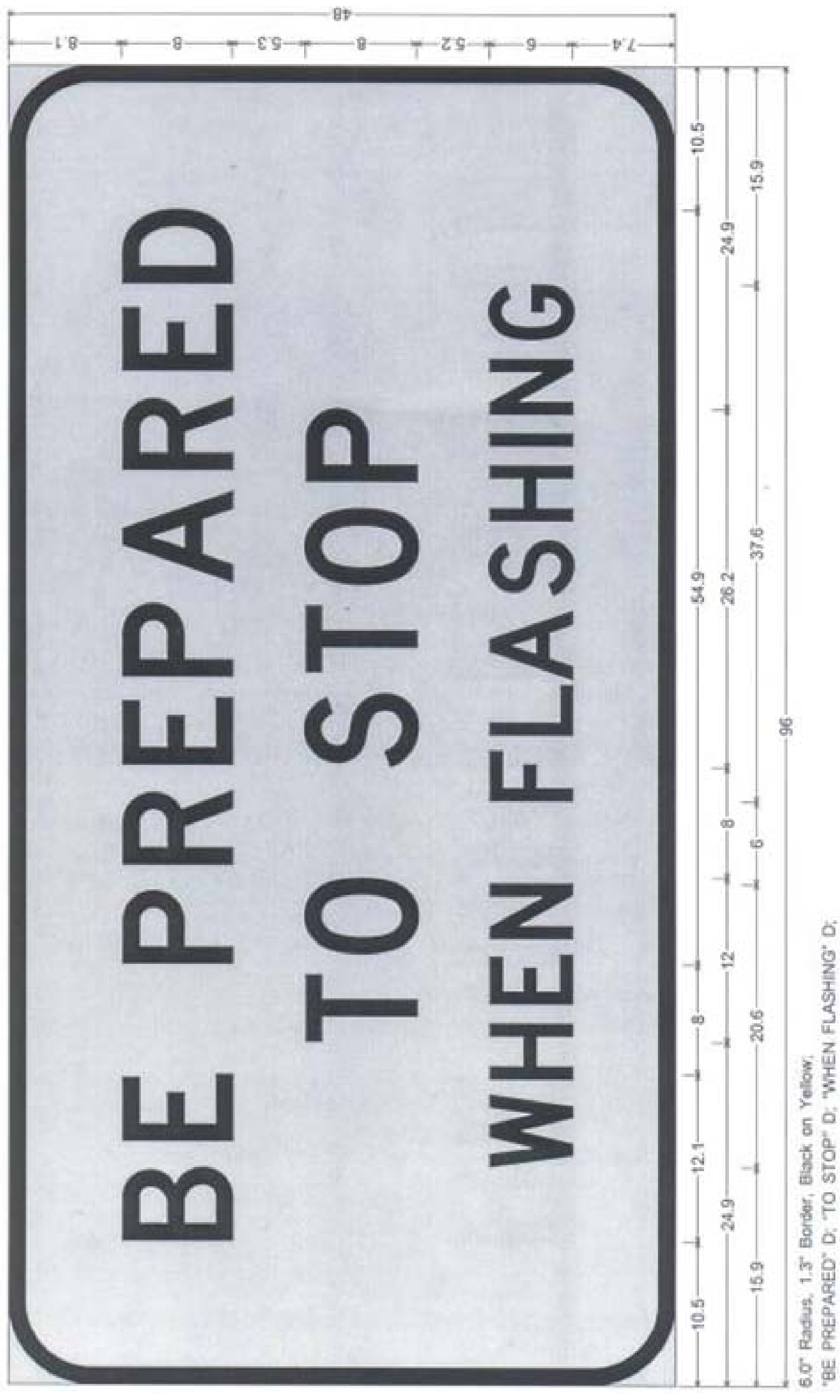


Figure 5. Layout of the Overhead AWEGS Sign.

Improved Flashing Operation

The flashing beacon operation at all AWEGS locations is powered by a signal from the AWEGS computer. The current flashing beacon operation meets the *MUTCD* (*15*) guidelines. Section 4K.01 of the *MUTCD* provides the following guidelines for the operation of a flashing beacon:

- Beacons shall be flashed at a rate of not less than 50 nor more than 60 times per minute.
- The illuminated period of each flash shall not be less than one-half and not more than two-thirds of the total cycle.

The signing and safety experts taken to the AWEGS site suggested the use of a flashing pattern known as the "stutter flash." While there are no established standards or specifications for the stutter flash on signs, Section 4L of the *MUTCD* (*15*) provides the following guidelines for the use of stutter flash for in-pavement lighting.

- The flash rate for in-roadway warning lights at crosswalks shall be at least 50, but not more than 60, flash periods per minute.
- The flash rate shall not be between 5 and 30 flashes per second to avoid frequencies that might cause seizures.

Currently there are some Federal Highway Administration studies that are evaluating the impacts of stutter flash operations at mid-block pedestrian crossings. However, improving the attention value of the W3-4 sign is strongly desirable due to their critical nature. Also, AWEGS beacons are operated by the AWEGS computer, and hence it was not very difficult to program stutter flash operations and implement them in the field. Based on the above requirements, the AWEGS computer was configured to provide a stutter flash with the following on/off configuration:

1. 0.1 seconds — On
2. 0.1 seconds — Off
3. 0.1 seconds — On
4. 0.1 seconds — Off
5. 0.1 seconds — On
6. 0.5 seconds — Off

This configuration results in a flashing operation that meets the *MUTCD* (*15*) guidelines in the following manner and is illustrated in Figure 6:

- a flash rate of 60 times per minute and
- a flash rate of three flashes per second to avoid frequencies that might cause seizures.

Figure 6. The Overhead Sign and Beacon Configuration.

The response from the operators and the users of the overhead sign/beacons configuration has been very positive. All the district engineers and senior technicians preferred the stutter flash to the normal flash. The sign and flashing beacons now have a high attention value, especially at night. TTI researchers conducted speed studies on the eastbound approach in Brenham to evaluate the impact of the overhead sign with the modified flash pattern. Figure 7 illustrates the impact of the overhead sign and the stutter flash on the approach speeds on the eastbound approach in Brenham. The average speeds decreased by about 9 mph, and the 85th percentile speeds decreased by about 10 mph. This clearly shows that the overhead sign with the stutter flash reduced the approach speeds, which will have a positive impact on intersection safety.

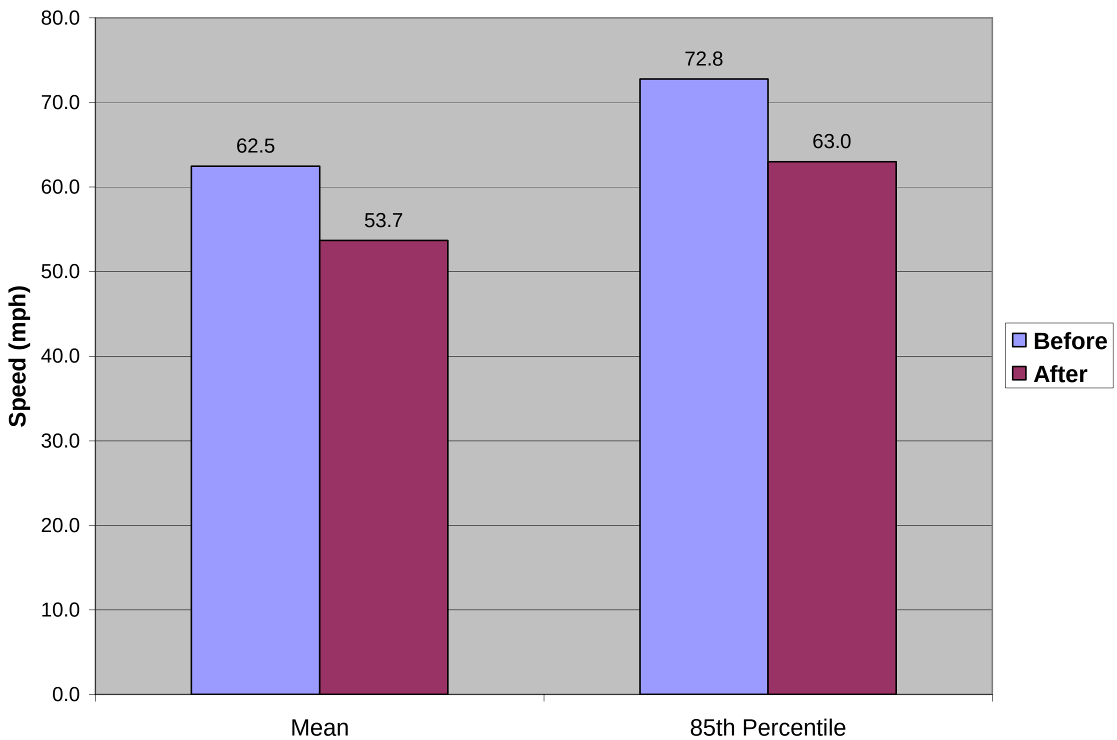


Figure 7. Impact of the Overhead Sign and Stutter Flash on Approach Speeds in Brenham.

Detector Failure

Fully operational advance detector traps installed upstream of the intersection in each lane on the main-street approaches, together with dilemma zone detectors at the intersection, are essential for the proper performance of AWEGS. The upstream advance trap detectors are used to calculate the dilemma zone of each vehicle approaching the intersection on the main-street approaches and to predict the vehicle's arrival on the dilemma zone detector furthest from the intersection. The dilemma zone detectors are monitored by AWEGS to predict when a phase is going to gap out when there are conflicting calls on other side-street and arterial left phases. Failure of any one of the advance trap detectors or the dilemma zone detectors will affect the performance of AWEGS and its ability to properly predict the end of green phases on the main street and provide advance warning of 5 to 6 seconds to motorists.

TTI researchers improved the AWEGS algorithm to detect the failure of advance trap and dilemma zone detectors and minimize their influence on AWEGS performance. The leading detector in each upstream advance trap is called the “ADA” detector, while the trailing detector is called the “BDA” detector. Dilemma zone detectors are called “CDA” detectors in AWEGS, with the furthest detector from the intersection called CDA 1. AWEGS recognizes and treats the following detector failures.

Advance Trap Detector ADA Failure

A vehicle approaching the AWEGS intersection in one of the main-street lanes will be detected first by the ADA detector of the advance trap installed in the lane. AWEGS records and keeps track in its memory of the actuation time of the ADA detector in milliseconds since midnight. When the BDA detector in the same lane is actuated later, AWEGS records the actuation time of the BDA detector in milliseconds since midnight and calculates the travel time from ADA to BDA. Since the actuation time of each detector is recorded in milliseconds since midnight, AWEGS takes into account in the calculation of the travel time if the clock rolls around midnight, in case one of the detectors was actuated before midnight and the other after midnight. The calculated travel time from ADA to BDA is compared to a lower and upper limit for travel time from ADA to BDA. The limits are calculated by AWEGS based on the 50^{th} percentile and 85^{th} percentile speeds for the main-street approach that the lane belongs to. If the calculated travel time is less than the lower limit, which means that the detected vehicle is driving at a very high speed (higher than the 99^{th} percentile speed), the vehicle’s travel time from ADA to BDA is set to the lower limit. On the other hand, if the calculated travel time is greater than the upper limit, the vehicle’s travel time is set to a calculated mean of the travel time of the last X vehicles. The X vehicles number is dependant on the “beta” coefficient that can be set in the “Phase Settings” data entry screen. The default beta value is 0.05, which results in the last 20 vehicles being used for calculating the mean travel time.

If the ADA detector of an advance trap fails, the last recorded actuation of the detector in milliseconds since midnight will be very old, and consequently the travel time from ADA to BDA of the last vehicle detected on BDA will be greater than the upper limit for travel from ADA to BDA. Therefore, the travel time of the vehicle detected on BDA will be set to the mean travel time of the last 20 vehicles.

Advance Trap Detector BDA Failure

As mentioned in the treatment of the ADA failure, AWEGS records the time that the ADA and BDA detectors were actuated. Anytime AWEGS detects a vehicle on the ADA detector, it sets a time into the future when it expects the vehicle to arrive on the BDA detector. The future time is equal to the time when ADA was actuated plus the upper limit for the travel time from ADA to BDA. If the expected vehicle arrives on BDA earlier than the expected time, AWEGS proceeds with its normal calculations using the actual travel time of the vehicle from ADA to BDA. Otherwise, if the expected time when the vehicle is supposed to be on the BDA detector passes without the vehicle showing on BDA, AWEGS proceeds with its calculations and decision-making process with a value of travel time from ADA to BDA equal to the mean travel time between ADA and BDA.

Advance Trap Detectors ADA and BDA Simultaneous Failure

When both ADA and BDA detectors of an advance trap fail, especially if there is only one lane per approach, AWEGS will lose its look-ahead feature as compared to the traffic signal controller and continue to work on the assumption that there are no vehicles upstream of the dilemma zone detectors. Consequently, when the main-street phase is ready to gap out and there is a call on a conflicting phase, AWEGS will start flashing the advance warning beacons to provide advance warning to motorists. In some cases, this might result in very long intervals of advance warning before the onset of yellow for the main-street phases.

Dilemma Zone Detector CDA Failure

Dilemma zone detectors on a main-street approach to an intersection are usually tied together and come back to the cabinet on a single lead-in wire. Consequently, by monitoring the dilemma zone detector input in the cabinet, it would be very difficult to detect the failure of any single one of the dilemma zone detectors on an approach if the other detectors continue to function normally. However, if all the dilemma zone detectors on an approach fail or the lead-in wire was damaged somehow, the amplifier will fail in the safe mode, i.e., it will show a constant call on the dilemma zone detectors for the given approach. On the other hand, if the amplifier that the dilemma zone detectors feed into in the cabinet fails, AWEGS will see a continuously off dilemma zone detector for the given approach. In both cases AWEGS will log a message into the detector failure data logging file (.DetFail file) indicating whether the detector has been on or off for more than 1 hour continuously. AWEGS will be affected and handles each type of failure differently. If the amplifier fails and the dilemma zone detector input to the controller and AWEGS is continuously off, the controller and AWEGS will both think that the dilemma zone detectors have gapped out. AWEGS will continue to function normally because it is seeing what the controller is seeing. That is, AWEGS's prediction of the end of green phase on the main-street phase will not be affected. On the other hand, if the dilemma zone detectors fail and the amplifier continues to function normally by failing in the safe mode, indicating that there is a continuous call on the dilemma zone detectors, the controller will place an extension on main-street phases, and the main-street green phases will max out each time. In this case AWEGS will continue to function normally and will provide a few seconds of advance warning before the phase maximum is reached because it detects the extension calls and knows the maximum green length of main-street phases.

Queue Detection

Frequently signalized intersections experience long queues on their approaches. While this happens on a regular basis in urban and suburban areas, it does happen sometimes at isolated intersections. On high-speed approaches long queues can cause an unsafe scenario if the queue extends a significant distance upstream of the intersection. This situation can get more dangerous if there is a horizontal curve on the approach to the intersection, which may prevent the high-speed motorists from seeing the back of the queue in time.

Based on observations and input from TxDOT, TTI researchers modified AWEGS to continue to flash the beacons for motorists approaching the intersection in such scenarios. A stop-bar detector was installed in each lane on the high-speed approaches. These stop-bar detectors were spliced (in the case of multiple lanes) and were brought back to the cabinet for each approach. It should be noted that these stop-bar detectors are brought back separately from the dilemma zone detectors and function as a queue detector. Such a configuration meets the Nader's layout (5) followed by TxDOT. The AWEGS algorithm monitors the stop-bar detector and, based on some user-defined parameters, determines the presence/absence of a queue. The user is provided the choice in the "System Parameters" data entry screen of AWEGS of whether to turn on or off the "Stop-Bar Detector Queue Flashing" option for main-street phases. AWEGS then continues to flash the beacon even after the onset of green for the approach until the queue is deemed to have dissipated. This provides an indication to the motorists approaching the intersection at a high speed to slow down if a queue is present at the intersection.

Motorist Response

AWEGS can be effective only if motorists can notice the W3-4 sign and flashing beacons, understand the sign, and respond to it. TTI researchers relocated one of the video cameras at the AWEGS location in Brenham to obtain video on the eastbound approach. The camera was installed on one of the luminaires on the approach. The camera received power from the luminaire and sent the video back to the signal controller cabinet wirelessly. The objective of this camera was to record and observe the responses of motorists, especially truck drivers, to the onset of beacons flashing. A digital video recorder (DVR) was installed in the signal cabinet, and a few days of data were recorded.

The video obtained from this camera had some limitations. While the camera was able to see the onset of the beacons flashing, it did not see the brake lights come on in the vehicles when the beacons started flashing. It was also not possible to see the signal status, which has a significant impact on the motorist's reaction on the approach. Hence, it was decided to prepare a small questionnaire and conduct an informal survey at the site in Brenham. TTI researchers met with some truck drivers that stopped in the truck rest area on the westbound approach of the intersection and conducted the survey. In addition, TTI researchers also visited numerous business establishments in the vicinity of the intersection and conducted the survey after obtaining permission from the business owners. Finally researchers visited the Blue Bell ice cream factory in Brenham and submitted the survey to the company truck drivers. Table 2 illustrates the survey used in Brenham.

The motorists surveyed generally had a good understanding of the AWEGS system and the related signs in the area. Specifically, a majority of the respondents understood the function of the W3-3 sign and beacons. Most of the respondents stated the correct function of the W3-4 sign and the flashing beacons. However, since the beacons of the W3-3 sign and the W3-4 signs were flashing simultaneously, some of the respondents confused the function of the W3-3 sign with the W3-4 sign. This response is not unexpected because normally if a W3-3 sign has beacons, they are flashing continuously. A majority of the truck drivers, however, understood the functions of the signs accurately and expressed an appreciation for the AWEGS deployment to reduce the dilemma the drivers face at the onset of yellow.

Table 2. Survey Used in Brenham for Motorist Understanding of AWEGS.

1	Vehicle Type (Car/Truck)	
2	Do you travel regularly on this roadway? (Yes/No)	
3	Did you notice the sign? (Photos of W3-3) (Yes/No)	
4	What does the sign mean?	
5	Did you notice the beacon on the sign? (Photos of W3-3) (Yes/No)	
6	Was the beacon flashing? (Yes/No)	
7	What do the sign and flashing beacon mean?	
8	Did you notice the sign? (Photos of W3-4) (Yes/No)	
9	What does the sign mean? (Photos of W3-3)	
10	Did you notice the beacon on the sign? (Photos of W3-4) (Yes/No)	
11	Was the beacon flashing? (Yes/No)	
12	What do the sign and flashing beacon mean?	
13	Summary: Understanding, Speed Change, Location of the Sign, System	

AWEGS Interface Improvements

TTI researchers modified the AWEGS graphical user interface (GUI) to:

1. reduce the number of data elements that need to be entered by a user for a new AWEGS installation in order to simplify the data entry process;
2. provide the user with a number of data logging options; and

3. revamp the AWEGS main application and intersection windows to provide the user with a quick view of AWEGS and intersection status.

The following sections provide a more detailed description of the AWEGS GUI improvements.

Reduce Data Entry Requirements

The AWEGS algorithm requires a number of inputs and outputs to perform its task of predicting the end of green on main-street approaches and provide motorists with advance warning of 5 to 6 seconds. The data requirements of AWEGS include the status of main-street phases, 50th percentile and 85th percentile speeds on main-street approaches, location and status of advance trap detectors installed for AWEGS, location and status of dilemma zone detectors, status of stop-bar detectors, flashing mode settings, general system parameters, and a map of the digital input/output (I/O) wiring of the various inputs and outputs required by AWEGS. The data required by AWEGS are stored in Extensible Markup Language (XML) format in a configuration file called "AWEGS.XML" that is located in a specific directory on the personal computer (PC) where AWEGS is running. The AWEGS configuration file is automatically read and loaded when AWEGS is started. Most of the data contained in the configuration file are generic and depend on the intersection type, whether it has one lane or two lanes per each main-street approach, especially the digital I/O wiring map and number of advance trap detectors. On the other hand, some of the data in the configuration file are specific to the intersection where AWEGS is installed.

TTI researchers redesigned the AWEGS configuration file, GUI menus, and data entry screens to reduce the number of data elements needed to be entered for a new AWEGS installation and to simplify the data entry process. TTI researchers designed two standard configuration files for AWEGS data requirements. One of the configuration files is designed for intersections with one lane per main-street approach, while the other is for intersections with two lanes per approach. TTI researchers also redesigned the AWEGS menus and data entry screens available in AWEGS. Most of the generic data entry screens in AWEGS that enable the user to modify the common intersection data are by default shaded (disabled) when AWEGS is started. The user can enable the generics data entry screens through the "Enable Advanced Menu Options" under the "AWEGS" menu. The intersection-specific data that the user needs to customize for a new installation, like phase minimum greens, passage time, 85^{th} percentile speed, etc., are usually filled with dummy data. After starting AWEGS, the user can access these data screens, enter the new data, and then save the new data to the existing configuration file where the old data are replaced.

As part of the data entry simplification, TTI researchers also converted all data elements required by AWEGS that can be calculated from other user-entered data elements into formulas that are automatically calculated by AWEGS once the user enters the relevant data. For example, the distance between the leading edges of the detectors in each advance trap is calculated once the user enters the distance of the leading edge of each detector in the trap to the stop bar. This method minimizes the possibility of human error in the calculations and simplifies the data entry task of the user.

The data elements a user has to modify/enter for a new AWEGS installation are discussed in the following sections.

Phase Settings Data Entry Screen

This screen includes main-street phases' minimum green times, maximum times, passage times, dilemma zone detectors' distance from the stop bar, 50^{th} percentile approach speed, 85^{th} percentile approach speed, direction of phase (i.e., east, west, north, or south), side-street and arterial left phase detector delays, and whether the "Memory On" feature is on or off for each phase.

Advance Detector Settings Data Entry Screen

This screen includes each advance trap detector's leading edge distance from the stop bar and from the dilemma zone detector furthest from the intersection for the main-street phases.

Flasher Settings Data Entry Screen

This screen includes the flashing beacons' mode (i.e., either STUTTER or NORMAL) and the beacons' on and off interval settings.

Ring Structure Data Entry Screen

This screen includes the ring a phase belongs to and its concurrent phases, especially for main-street phases.

The Intersection Name Data Entry Screen

This screen includes the city and intersection name.

Data Logging

TTI researchers modified the AWEGS GUI to provide the user with an array of data logging options, enabling him or her to log into daily data files, both AWEGS and intersection raw and performance data. The formats for the name of the data logging files are all the same and consist of date and time in the following format: "YYYYMMDD-HHMM." The extension of the data logging files depends on the data logging option selected. Each data logging file is closed at midnight, and a new file is opened with a name depending on the new date and the time since midnight when it was opened. Each entry in the data logging file is preceded by a time stamp that includes the data and time to the millisecond when the event took place. The data logging options provided by AWEGS include those discussed in the following sections.

General Events (.Ada Files)

Selecting this data logging option will log into a file with the extension ".ada," which includes stop-bar detector actuations, dilemma zone detector actuations, advance trap detector actuations, and traffic signal system events like start of green, yellow, all red, and red for main-street phases. Decisions made by AWEGS are also logged into this file, like start and end of flashing beacons for each main-street phase, phase holds placed to help vehicles that might be caught in the dilemma zone around the end of green of main-street phases, the duration of each hold, and AWEGS logic status. At the end of the day before closing the file, AWEGS will record a summary of the total number of vehicles that were detected on each one of the detectors in the advance trap detectors, and the number of the main-street phase's green and yellow starts per day.

Advance Warning (.Wrn Files)

Selecting this data logging option will record into a file the duration of the advance warning period provided to motorists by AWEGS before each onset of yellow on the main-street phases.

False Flashing (.FFlash Files)

This option logs into a file an entry every time a false flash is detected. False flashes usually occur when AWEGS detects a vehicle call on one of the phases that conflict with main-street phases like side-street and arterial left phases and if the vehicle call goes away (like a left turn on a permissive left-turn phase or a right-turning vehicle actuating a detector in a lane shared by through and right-turning vehicles.

Main-Street Phase Holds (.Hold Files)

Selecting this option will record an entry to a log file each time AWEGS decides to place a hold on one of the main-street phases. AWEGS places a hold anytime it realizes that a vehicle detected by the advance trap detectors is in its dilemma zone, the vehicle has not reached the first dilemma zone detector yet, and AWEGS is predicting that the main-street phase is going to end soon before the vehicle can make it to the first dilemma zone detector. The duration of the hold is usually long enough to get the vehicle to the first dilemma zone detector.

Speed Files (.Spd Files)

Selecting this data logging option records into a log file an entry with the speed of the vehicle that was just detected on the second pair of each advance trap as calculated by the AWEGS algorithm. AWEGS records at the beginning of the file the 50^{th} and 85^{th} percentile speeds for each phase as entered by the user.

Detector Failure (.DetFail Files)

This data logging option logs into a file a record every time AWEGS detects that one of the advance trap detectors, dilemma zone detectors, or stop-bar detectors was continuously actuated or did not have any actuations for more than 1 hour.

AWEGS Status Displays

TTI researchers also improved the two main displays provided by AWEGS, including the application display and the intersection display. The main application display was modified to provide the user at a quick glance with the status of the main-street phases (green, yellow, or red), ring status for both rings 1 and 2 (minimum green, extension, maximum, green rest, yellow change, red clearance, red rest, or undefined), and daily statistics since midnight for each advance trap used by AWEGS, including speed and class of the last detected vehicle, total number of cars detected by the trap since midnight, and total number of trucks detected by the trap since midnight. The intersection display provides the user with the status of each main-street phase (green, yellow, or red); each ring status (minimum green, extension, maximum, green rest, yellow change, red clearance, red rest, or undefined); stop-bar, dilemma zone, and advance trap detector status (on or off); the type of the last vehicle detected on each advance detector trap (car or truck); the length of the advance warning period in milliseconds that was provided to motorists before the onset of the last yellow for main-street phases; and AWEGS status in terms of its decision-making process. Figure 8 and Figure 9 illustrate the main application display and the intersection display.

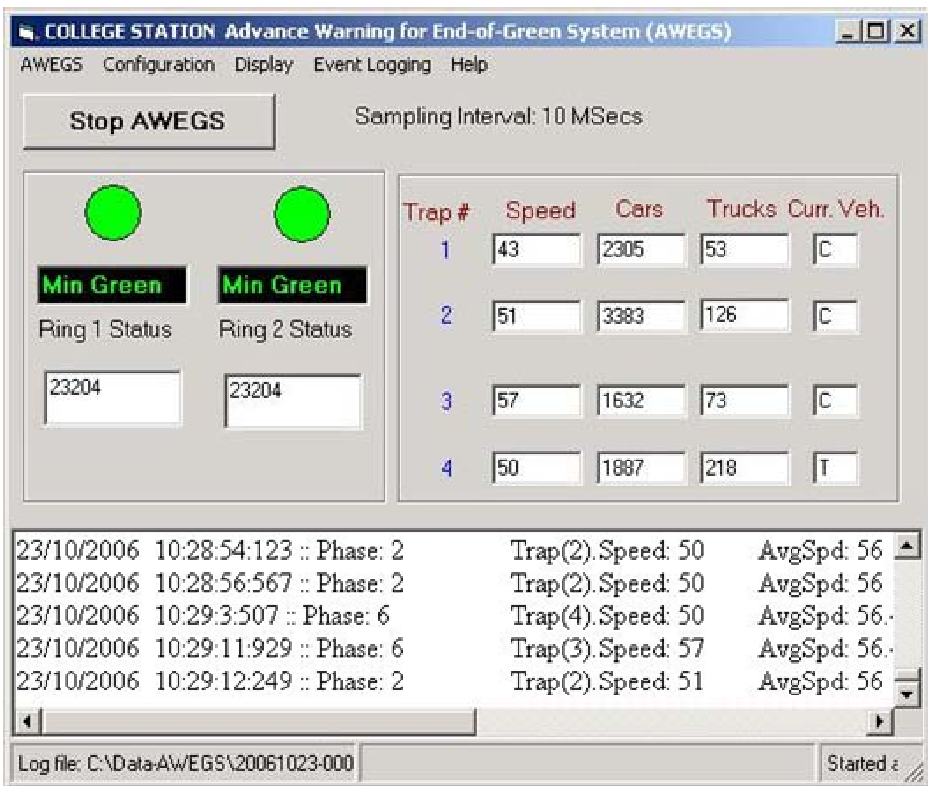


Figure 8. AWEGS Main Application Display.

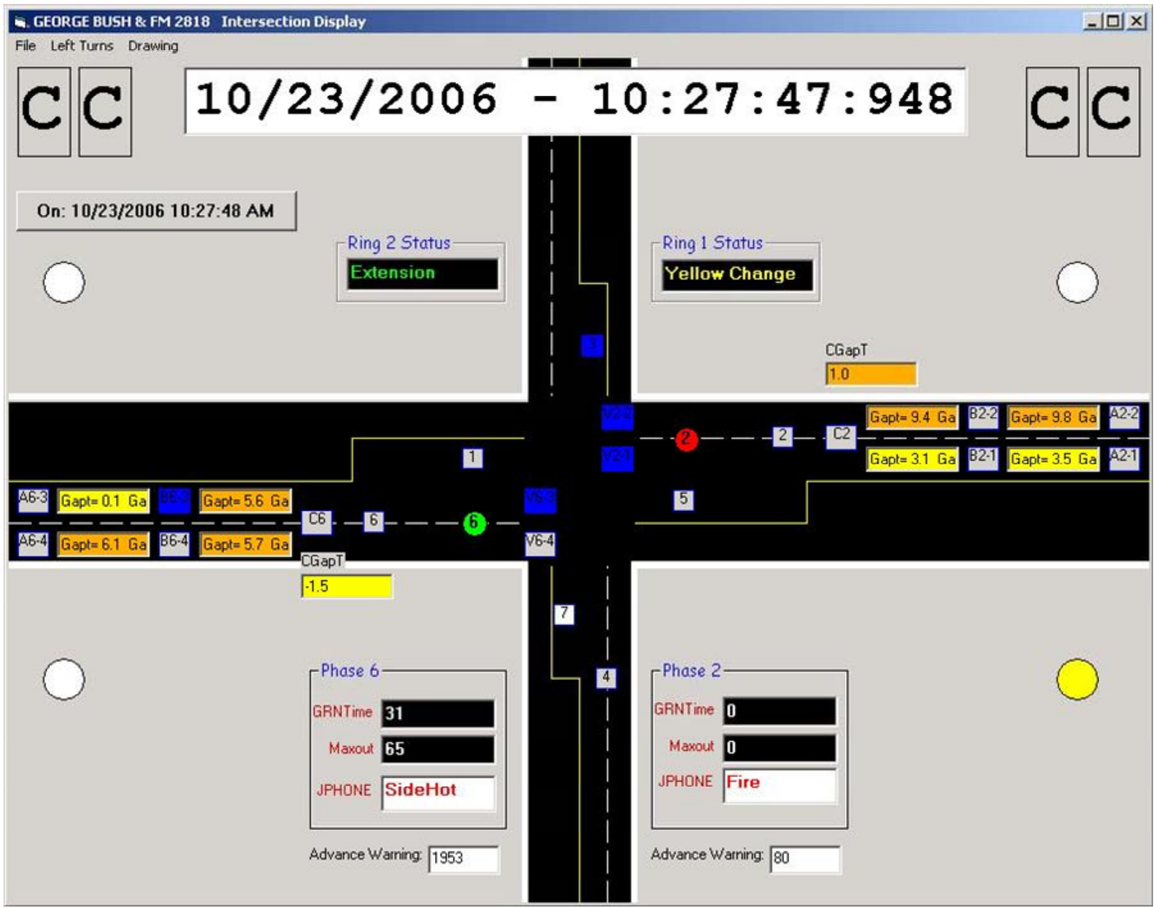


Figure 9. AWEGS Intersection Display.

AWEGS DEPLOYMENT

TTI researchers and the project panel reviewed several sites in the Waco District, Atlanta District and Bryan District to select a site for a new AWEGS installation. After a detailed review, a site was selected in College Station, in the Bryan District. This site currently is a high accident location and warranted installation of some measures to improve safety. Secondly, since the location is in College Station, the testing, installation, and evaluation of AWEGS by TTI personnel becomes much easier. The selected site is very close to the Texas A&M University campus in College Station, as illustrated in Figure 10.

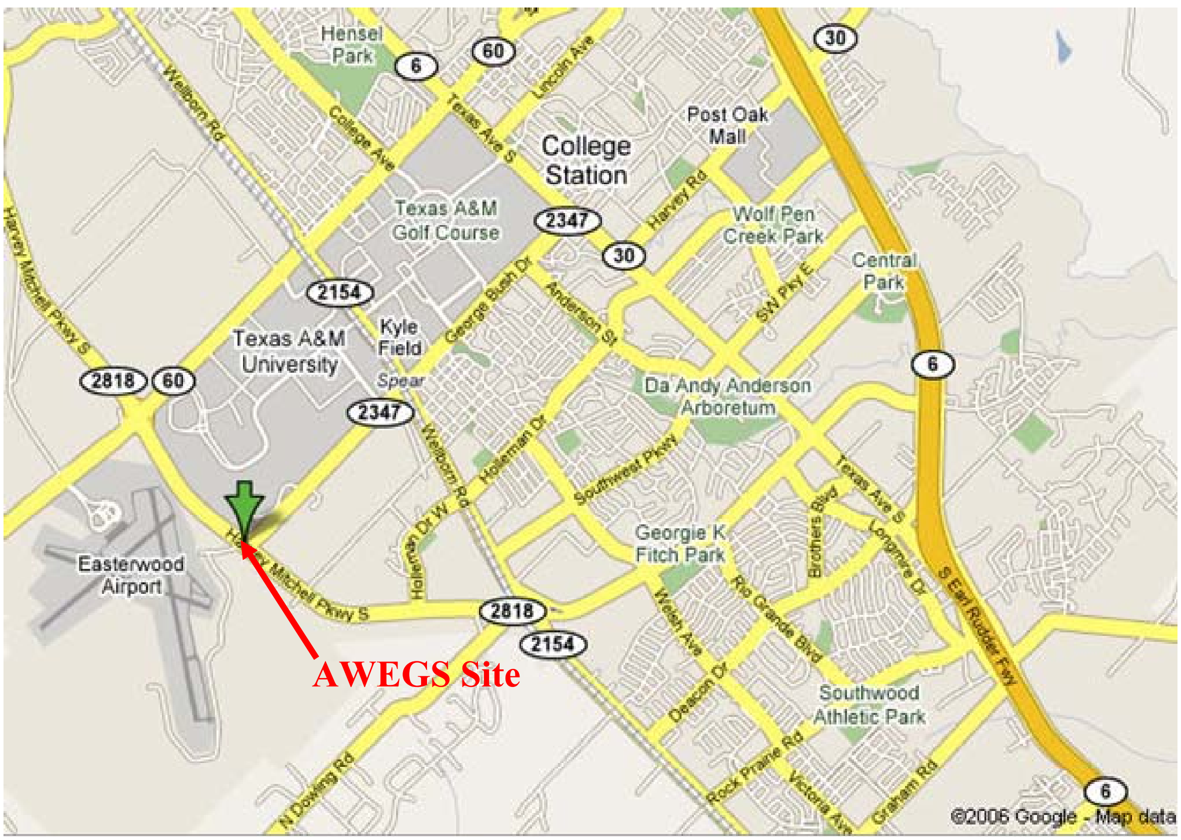


Figure 10. Location of the AWEGS Site in College Station.

Existing Site Conditions

The site in College Station is at the intersection of FM 2818 (Harvey Mitchell Parkway) and George Bush Drive (FM 2347). AWEGS was installed on the FM 2818 approaches. FM 2818 is a high-speed four-lane arterial (north-south). The posted speed limit on both approaches is 60 mph. FM 2818 carries a lot of traffic to and from Texas A&M University and also serves as a bypass to the cities of Bryan and College Station. The arterial has an average daily traffic (ADT) of over 25,000 vehicles. The westbound approach from Texas A&M University campus carries a significant amount of turning traffic periodically. The eastbound approach from the airport is fairly light. Traffic is very heavy during the AM peak and the PM peak periods. However, there are numerous small surges in traffic demands numerous times during the day coinciding with the start and finish of classes. This intersection is also one of the entrances and exits used for special events like football games, graduations, and other athletic events which have significant traffic demands. Figure 11 illustrates the intersection layout and the phase numbering scheme. The intersection also has protected-permissive phasing on the arterial left turns, and the side streets use split phasing sequence.

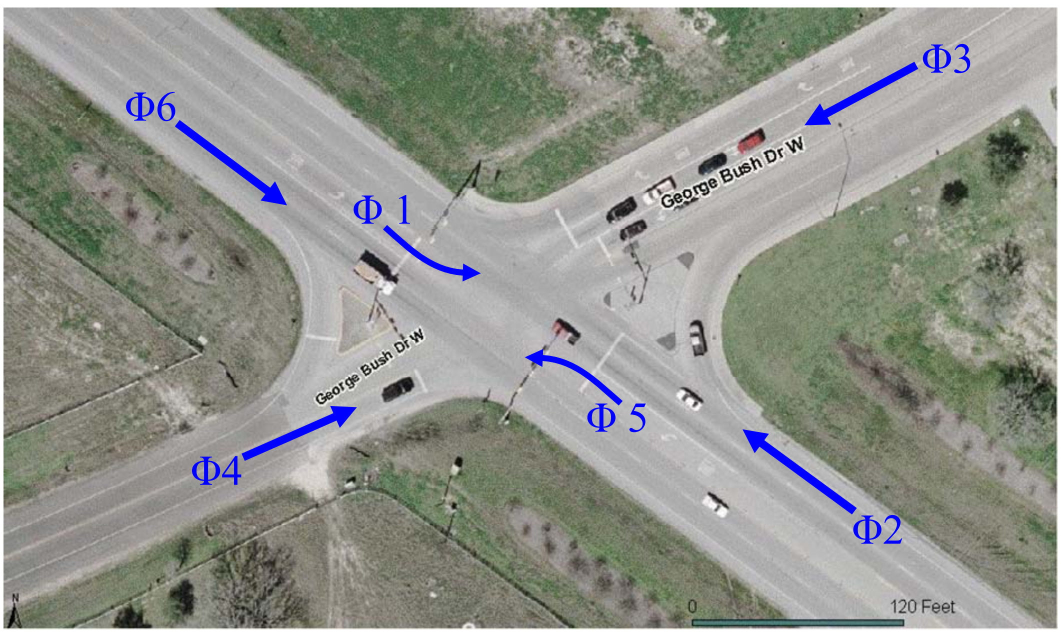


Figure 11. Intersection Layout for AWEGS Site.

This signal is operated by the City of College Station and uses an EPAC 300 TS-1 controller. The intersection is fully actuated with inductive loops on all four approaches. Figure 12 illustrates the existing detectors on the high-speed approaches of FM 2818. Figure 13 illustrates the detector layout on the side street.

Proposed Intersection Layout

As mentioned earlier, AWEGS was designed to operate within the current TxDOT practice of dilemma zone detector design (5). It is clearly seen from Figure 12 and Table 1 that the existing detector layout is not consistent with TxDOT practice. Hence, researchers decided to install dilemma zone detectors using project funds. This was possible because the TxDOT Bryan District had secured some Highway Safety Funds for installation of some safety measures at this intersection due to its high accident rate. The availability of these additional funds freed up some of the funds allocated for the purchase of AWEGS infrastructure. These funds were used to install the dilemma zone detectors. Figure 14 illustrates the detector and sign layout for AWEGS installation at the College Station site. The AWEGS installation included advance detectors at about 900 feet from the stop bar, overhead AWEGS signs at about 475 feet from the stop bar, and dilemma zone detectors for a 60 mph approach. The contractor did not install the stop-bar detectors in the through lanes due to some miscommunication.

After the contractor installed the dilemma zone detectors and the advance detectors, and based on speed studies conducted earlier, TTI researchers and the City of College Station engineers programmed the signal controller for the new detector configuration. The updated parameters included the duration of the yellow interval and all-red interval and the passage times. Table 3 illustrates the modification made to the settings.

Table 3. Existing and Proposed Controller Parameters.

	Yellow Interval (in Seconds)		**All-Red Interval (in Seconds)**		**Passage Time (in Seconds)**	
	Existing	***Proposed***	***Existing***	***Proposed***	***Existing***	***Proposed***
Phase 2	5.8	5.0	1.0	1.0	7.5	2.0
Phase 6	5.8	5.2	1.0	1.0	7.5	2.0

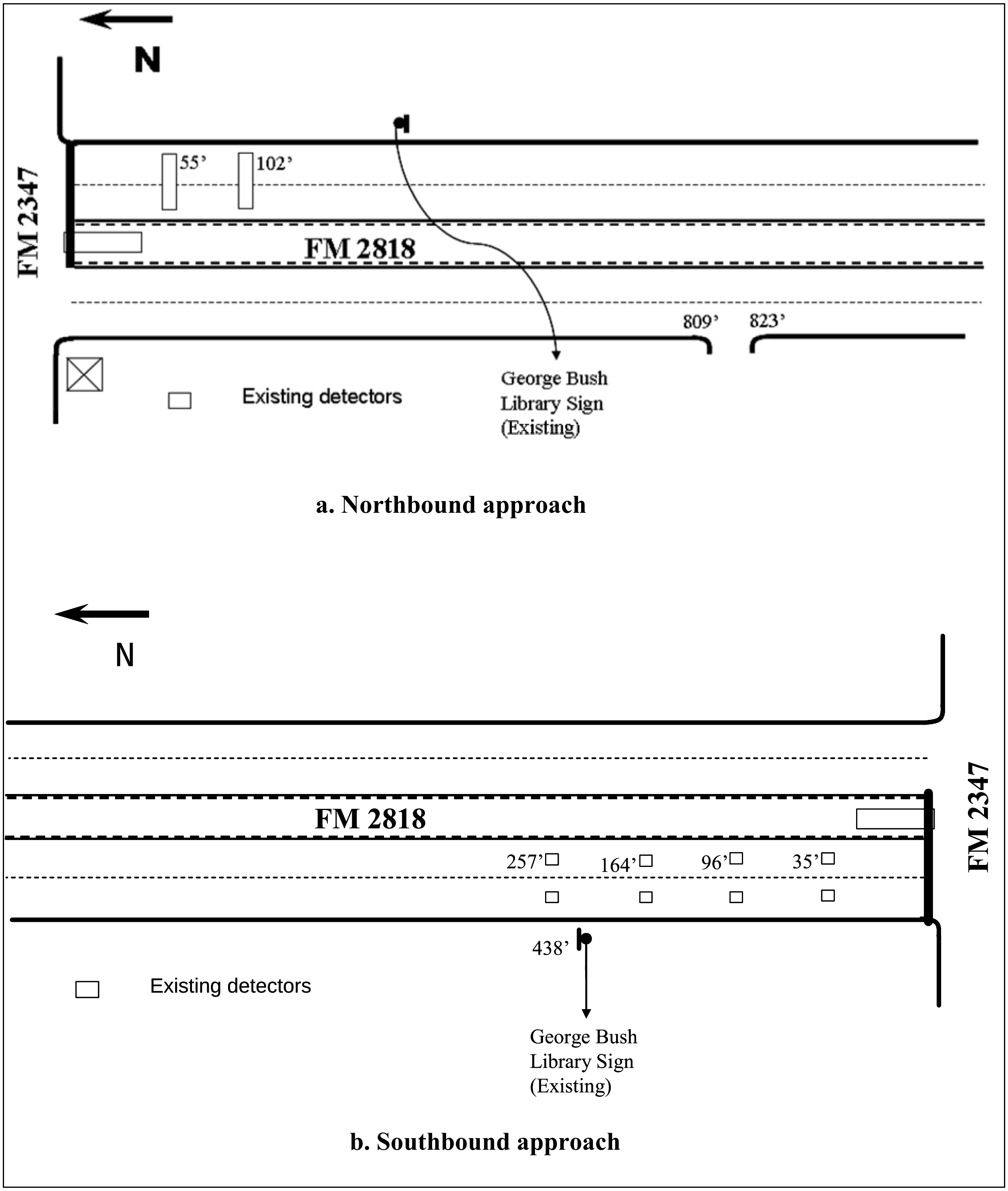


Figure 12. Existing Detector Layout along FM 2818.

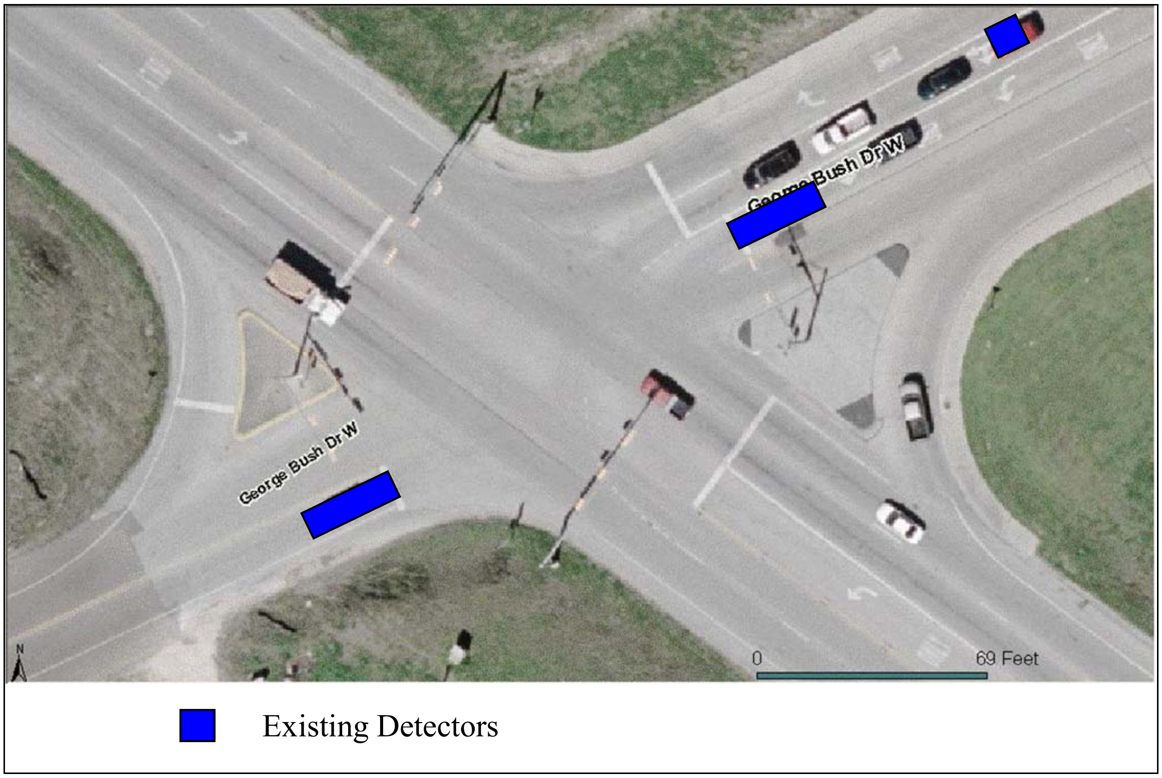
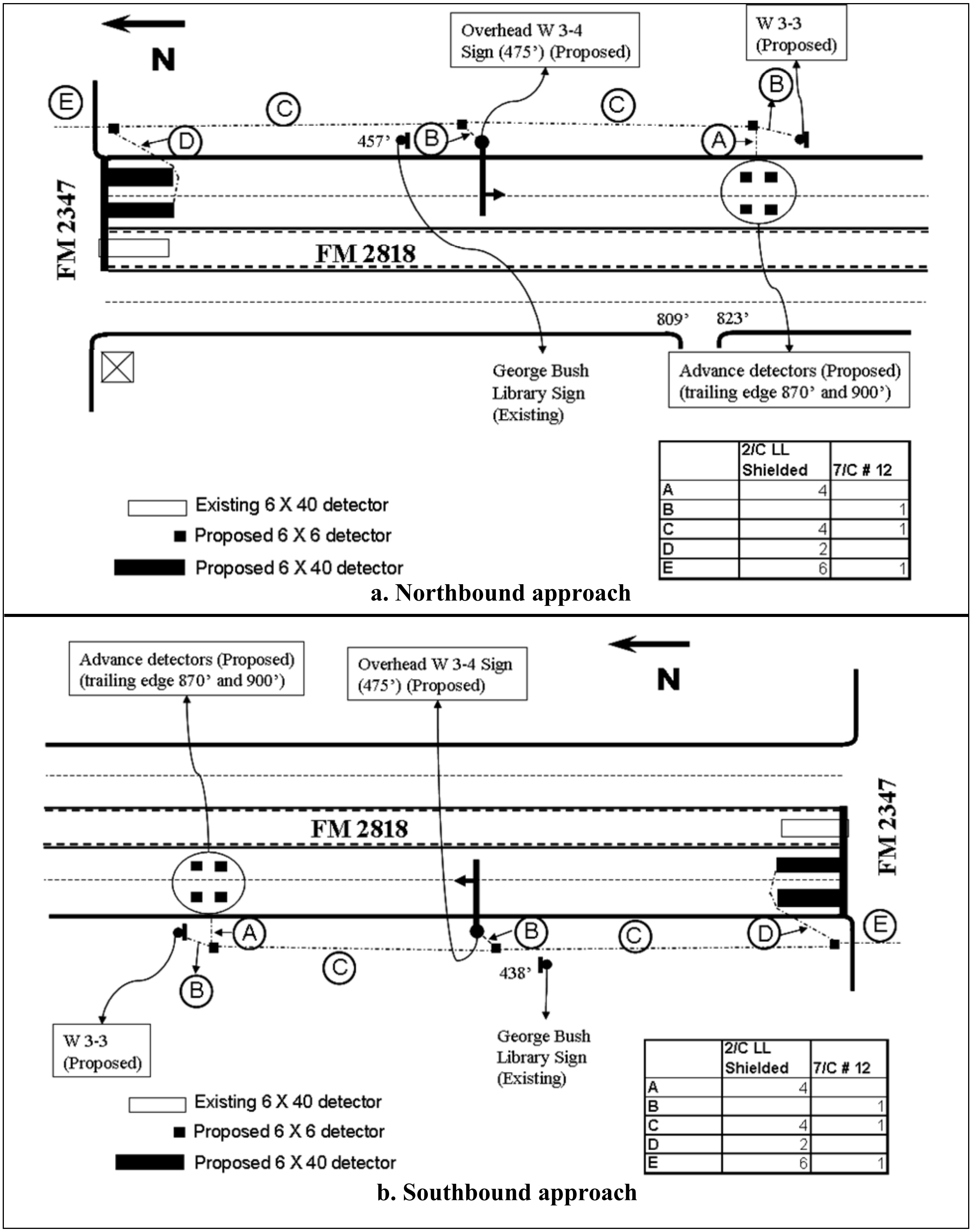


Figure 13. Existing Detectors on the Side Street.

AWEGS Implementation

A new cabinet was purchased for installing the AWEGS equipment. The existing cabinet was a very old cabinet and had no space for the additional equipment. Since some of the AWEGS infrastructure was being funded from a separate Highway Safety Fund, some of the project funds were used to replace the existing cabinet. An R-44 cabinet of a height between 72 to 77 inches was specified and procured. The City of College Station technicians replaced the old cabinet with the new cabinet. Even before the detectors were installed, TTI researchers started installing equipment in the signal controller cabinet. AWEGS requires a significant number of pieces of equipment to be installed in the cabinet. These include a PC, a flasher panel, detector amplifiers, a separate detector panel for the advance detectors, a digi-board, timers, video detection equipment for evaluating red-light running, etc. Figure 15 shows the signal controller cabinet before and after the installation of AWEGS equipment.



	2/C LL Shielded	7/C # 12
A	4	
B		1
C	4	1
D	2	
E	6	1

a. Northbound approach

	2/C LL Shielded	7/C # 12
A	4	
B		1
C	4	1
D	2	
E	6	1

b. Southbound approach

Figure 14. Proposed AWEGS Layout.

a. Cabinet without AWEGS Equipment

b. Cabinet with AWEGS Equipment

Figure 15. Cabinet without and with AWEGS Equipment.

Once the new parameters were implemented, traffic behavior was observed for a few days. It was critical to observe traffic behavior because this intersection has a large amount of commuter traffic, and motorists would be acclimatized to the parameters of passage times and yellow intervals. TTI researchers and the city engineers wanted to make sure the motorists' response to the updated parameters was safe and proper. Only after the traffic had stabilized and gotten used to the new detector layout did TTI researchers start collecting before data for AWEGS evaluation. The before data were gathered by using video detectors for identifying red-light runners. The dilemma zone detectors were installed on May 12, 2006; the new parameters were implemented on May 16, 2006; and the before data were collected from May 26, 2006.

AWEGS Configuration

AWEGS requires numerous inputs and outputs for the algorithm to function. The following inputs from the cabinet to the algorithm are required:

- Status Bit A, Status Bit B, and Status Bit C for Ring 1 and Ring 2 (six inputs);

- phase on for arterial phases (two inputs);
- status of stop-bar detectors for all phases (six to eight inputs);
- status of advance detectors (two per approach lane) (four to eight inputs); and
- status of dilemma zone detectors for both arterial phases (two inputs).

The following outputs from the algorithm to the signal controller cabinet are required:

- Beacon 1 and Beacon 2 for both the arterial approaches (four inputs),
- phase hold for both the arterial approaches (two inputs), and
- heartbeat to the flasher panel (one input).

AWEGS requires the following field data for each location to be programmed into the algorithm:

- distance of all the advance detectors from the stop bar,
- distance of all the dilemma zone detectors from the stop bar, and
- 85^{th} and 50^{th} percentile approach speeds.

AWEGS requires the following data from the traffic signal controller for each location to be programmed into the algorithm:

- phase numbering scheme at the intersection;
- minimum green, maximum green, and passage times for the arterial movements;
- phasing sequence in the form of ring structure; and
- delays placed on some phases in the controller (delays are placed in the controller on the phases conflicting with the arterial phases).

Fine-Tuning

While the before data were being collected, the AWEGS software was configured and all the inputs were connected to the algorithm. The outputs from the algorithm to the signal cabinet were not connected. Hence, AWEGS was running in a shadow mode. AWEGS had various log files, mentioned in the previous chapter. During the shadow mode, the AWEGS operation was logged in all the log files. TTI researchers analyzed the log files to determine the functionality of AWEGS. Based on the performance and field observations, some parameters in the algorithm were fine-tuned.

Speed

One of the log files created is the speed log file. This file documents the speeds of each vehicle being calculated by the advance detectors. The speed is calculated by measuring the travel time between the two advance detectors. This speed is used to estimate the dilemma zone for each vehicle and then to estimate the travel time to the upstream edge of the dilemma zone and/or the travel time to the dilemma zone detector that is furthest from the stop bar. However, the algorithm has some boundaries for the travel time between the two advance detectors. The boundaries are to ensure that travel times that are abnormal due to a variety of reasons are not used. The upper limit of the boundary is a fixed value and is equivalent to the 99th percentile speed. The lower limit is equivalent to the 15th percentile speed. When the travel time between the two detectors is smaller than the lower limit (i.e., the vehicle is potentially traveling faster than the 99th percentile speed), the travel time is set to the lower limit. However, when the travel time is greater than that upper limit (i.e., the vehicle is traveling slower than the 15th percentile speed), the travel time is set to the rolling average travel time. The rolling average travel time is based on the travel time for the previous 20 vehicles on the approach.

TTI researchers conducted speed studies using a radar gun on the approaches to the intersection. The speeds were measured at the approximate locations of the advance detectors. These speed parameters were programmed into the AWEGS software. However, during the shadow mode operation of AWEGS, TTI researchers observed numerous messages about speed errors. This meant that the speeds being observed at the advance detectors were outside the limits set by the program. Hence, the speed log file being created by AWEGS was used to generate updated speed data, and the new speed parameters were programmed into AWEGS. Researchers immediately saw a reduction in the speed errors.

Stop-Bar Detection

Stop-bar detection at the intersection is necessary to monitor the vehicle calls. Ideally stop-bar detection is required for all the phases at the intersection. While stop-bar detectors for the phases that conflict with the major arterial through phases serve the function of calling those phases, stop-bar detectors for the arterial through phases serve the function of clearing the queues. As was noted in Figure 12, Figure 13, and Figure 14, there are no stop-bar detectors for the arterial through phases. Frequently long queues with heavy vehicles were observed for the arterial through movements. Many times this resulted in the phases gapping out in the presence of a queue. This was happening because the nearest dilemma zone detector was 275 feet from the stop bar. Hence, TTI researchers worked with City of College Station technicians to use the nearest of the old detectors for the arterial through movements for both the approaches. These detectors were programmed as stop-bar detectors so that they would be on until the queue dissipated. Once the queue dissipated, they would be turned off until the onset of yellow. Use of these detectors reduced the gap-outs being observed in the presence of a queue.

As was seen in Figure 13, the westbound approach has a stop-bar detector in the left lane and an upstream detector in the middle lane. Due to such detector configuration, the City of College Station technicians were operating this side-street phase as "memory on." This basically meant that any call that is placed by a vehicle over either of these detectors would be remembered by the controller and the phase serviced. However, as stated in the previous chapter, AWEGS requires a delay to be programmed in the controller for all phases that conflict with the arterial through phases. Placing a delay on the phase when the phase is on "memory on" results in the call on the middle lane detector not being registered by the controller. This was a unique situation that the TTI researchers had never faced at any of the other AWEGS locations. After some discussion, TTI researchers solved the problem in the following manner.

TTI researchers programmed an extension of 2.25 seconds in the detector amplifier for the detectors on the westbound approach. This extension would enable the call to be placed for a duration of 2.25 seconds after the vehicle leaves the detection area. Researchers then programmed a delay of 2 seconds in the controller for the westbound phase. Thus the objective of gaining some advance knowledge (before the controller) of the calls on the westbound approach was achieved while maintaining the integrity of the detection for this approach.

There is a single lane for the eastbound approach, and a stop-bar detector exists in this lane. There is a significant volume of right-turn traffic for the eastbound approach. TTI researchers had originally programmed a delay of 2 seconds for obtaining the advance knowledge of call on this phase. However, a large amount of right-turn traffic was placing calls on the controller and on AWEGS. Frequently AWEGS would respond by starting to flash the beacons, and before the arterial through phases could gap out, the right-turn traffic would dissipate. This causes AWEGS to flash the beacons for no reason, resulting in a false flash. TTI researchers increased the delay in the controller for the eastbound detectors and significantly reduced the number of false flashes.

Arterial Lefts

The type of left-turn treatment for the arterial movements has a significant impact on the configuration of AWEGS. When the arterial left-turn phases are protected, the configuration is simple. Delays of up to 2 seconds need to be programmed into the controller for these phases to obtain advance detector information. When the arterial left-turn phase is permitted, the configuration is very simple again. There are no conflicting phases to the arterial through movements. The real challenge comes when the left-turn phasing is protected-permissive. In this case the delay programmed into the controller has two purposes. One, the delay provides advance detector information. Two, the delay will also allow any vehicles turning left in the permitted portion to not place calls to the controller. For the second reason, the delay should be long enough to ensure that vehicles do not place an unnecessary call to the controller. This delay then becomes a function of the left-turn volume and the opposing through volume. As left-turn volume increases, the delay to be placed can increase. However, as the opposing through volume increases, the allowable gaps decrease and the delay can be decreased. Hence, field observations are crucial to determine the appropriate value of delay to be programmed.

TTI researchers made another change in the wiring of the left-turn detectors. At the earlier AWEGS deployments, the left-turn detectors were monitored at the phase check on the back panel. This meant that the vehicle call was received by the controller and AWEGS algorithm at the same time. The delay programmed was only being used for filtering out the permitted left-turn vehicles. This was not a problem because in the earlier deployments the left-turn volumes were either very low (Waco) or the phasing sequence being used (lead-lag in Brenham) was inherently solving the problem of advance detector information. In College Station also, AWEGS monitored the phase check only for arterial left turns. However, it was observed that the beacons started flashing at the onset of yellow numerous times. This was because AWEGS did not have advance knowledge of the left-turn calls and the left-turn volumes were higher at the College Station site. TTI researchers then started monitoring the arterial left-turn detectors on the detector panel instead of the phase check. This allowed advance knowledge of the left-turn calls. However, then the researchers started observing false flashing of the beacons due to arterial left turns. Considerable effort was made to program an appropriate delay to minimize the number of false flashes due to left turns.

EVALUATION

There are numerous ways of evaluating an AWEGS deployment. Primarily the evaluation can include the performance of the AWEGS algorithm. Criteria for evaluating the performance include the duration of advance warning being provided (average should be between 5 to 7 seconds), the number of false flashes (should be minimal), and the number of phase holds (should be minimal). AWEGS can also be evaluated by direct impact on traffic. This benefit is primarily seen in reduction of red-light running. TTI researchers collected before and after data for the AWEGS deployment.

The data collection process was logged to document a timeline of the events at the site and is illustrated in Table 4. As mentioned earlier, the new dilemma zone detectors were installed on May 11, the new dilemma zone detectors were in operation on May 16, and the red-light running data were collected from May 27. While AWEGS was operational from June 27, calibration of the program was necessary for a few days, and hence proper data were being collected from July 1. Some more calibrations like increasing the delay on arterial left-turn detectors, moving the left-turn detection monitoring from the phase check to detector panel, and correcting a wiring problem for video detection were made. Hence final AWEGS data were available from July 29, and red-light running after data were available from August 1. The following sections will further describe the evaluation of AWEGS deployment.

System Performance

As mentioned above, the first and foremost means of evaluating AWEGS deployment is to study its performance. Data collected from July 29 were analyzed for evaluating AWEGS performance. The function of AWEGS is to provide an advance warning before the end of green of the arterial phases to high-speed approach traffic. The system monitors almost all of the detections at the intersection, detections on the advance detectors on the arterial approaches, and the signal controller status. Based on the detector activity, AWEGS then predicts the termination of green about 6 to 8 seconds in advance for each arterial approach and starts flashing the advance warning beacons.

Table 4. Data Collection Log for AWEGS.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
5/7/2006	5/8/2006	5/9/2006	5/10/2006	**5/11/2006**	5/12/2006	5/13/2006
5/14/2006	5/15/2006	**5/16/2006**	5/17/2006	5/18/2006	5/19/2006	5/20/2006
5/21/2006	5/22/2006	5/23/2006	5/24/2006	5/25/2006	**5/26/2006**	5/27/2006
5/28/2006	5/29/2006	5/30/2006	5/31/2006	6/1/2006	6/2/2006	6/3/2006
6/4/2006	6/5/2006	6/6/2006	6/7/2006	6/8/2006	6/9/2006	6/10/2006
6/11/2006	6/12/2006	6/13/2006	6/14/2006	6/15/2006	6/16/2006	6/17/2006
6/18/2006	6/19/2006	6/20/2006	6/21/2006	6/22/2006	6/23/2006	6/24/2006
6/25/2006	6/26/2006	**6/27/2006**	6/28/2006	6/29/2006	6/30/2006	7/1/2006
7/2/2006	7/3/2006	7/4/2006	7/5/2006	7/6/2006	7/7/2006	7/8/2006
7/9/2006	7/10/2006	7/11/2006	7/12/2006	7/13/2006	7/14/2006	7/15/2006
7/16/2006	7/17/2006	7/18/2006	7/19/2006	7/20/2006	**7/21/2006**	7/22/2006
7/23/2006	7/24/2006	7/25/2006	7/26/2006	7/27/2006	**7/28/2006**	7/29/2006
7/30/2006	7/31/2006	**8/1/2006**	8/2/2006	8/3/2006	8/4/2006	8/5/2006
8/6/2006	8/7/2006	8/8/2006	8/9/2006	8/10/2006	8/11/2006	8/12/2006
8/13/2006	8/14/2006	**8/15/2006**	8/16/2006	8/17/2006	8/18/2006	8/19/2006
8/20/2006	8/21/2006	8/22/2006	8/23/2006	8/24/2006	8/25/2006	8/26/2006
8/27/2006	8/28/2006	8/29/2006	8/30/2006	8/31/2006		

New Dilemma Zone Detectors with RLR Dets
AWEGS Operational
Power Failure
Bad Data
Final AWEGS Data from 07-29-2006
RLR After Data from 08-03-2006

In order to ensure that a vehicle is not in its dilemma zone at the termination of green, sometimes AWEGS places a phase hold for special cases. These holds should be very few and can have a variable duration based on the needs of the vehicle for which the hold is being provided. AWEGS attempts to provide an advance warning for the end of green of about 6 to 8 seconds. AWEGS makes decisions on termination of green based on several assumptions regarding vehicle detection and operation. However, motorists do not always drive in a predictable manner. They sometimes slow down on an approach, and sometimes they speed up. To overcome this variability of driver behavior, the system monitors the signal controller to provide high-quality prediction. If the prediction is proving to be false, AWEGS has to catch up with the controller operations to warn the vehicle by delaying the termination of green when the vehicle is in the dilemma zone by placing a phase hold. Sometimes the advance detectors may detect the first vehicle of a platoon. Under the right conditions, AWEGS may start flashing the beacons after protecting the lead vehicle of the platoon because of conflicting calls. AWEGS does this because it has no way of knowing a platoon of vehicles is oncoming. This situation can result in advance warning of more than 6 to 8 seconds because the subsequent vehicles in the platoon may extend the phase.

Sometimes no advance warning on the arterial may be provided. This usually will happen because no advance warning is really necessary. This may happen when a call suddenly comes on a conflicting phase when there are no vehicles on the arterial approaches (as may happen during off-peak periods). Here, no need exists to provide any advance warning for the arterial approaches.

Sometimes the system is unable to distinguish a real detection on a detector from a false call. For example, a real detection on a side-street stop-bar detector is a vehicle waiting for a green on the side street. A false detection on the same detector is a left-turning vehicle from the arterial going over the same detector during an arterial left-turn movement. With inductive-loop detectors (ILDs), the amplifier in the cabinet is unable to distinguish this detection as being a false call. Hence, the AWEGS reacts to this false detection as if it were a true call, and AWEGS may immediately start flashing if conditions are right. However, the system usually soon recognizes the false call and stops flashing the beacons when it is safe to do so. This unnecessary flashing can be minimized by providing good intersection geometric design initially and improved directional detection capabilities

This situation sometimes leads to false calls and may result in a large variation in the warning time provided to approaching motorists. This case may even cause some false flashing. However, the AWEGS has been designed to minimize this variation in warning time and ensure that it does not have an adverse impact on approaching motorists.

Phase Holds

In order to better understand system performance, seven days of detailed data were examined from the AWEGS operations in College Station. Researchers analyzed these data to determine the hold patterns, the number of phase terminations, and the pattern of the advance warning being provided per typical day. Table 5 illustrates the statistics observed in College Station regarding the number of phase holds and the mean duration of phase holds for a week.

The table also illustrates the number of phase ends for each approach for a week from August 3, 2006, (Thursday) to August 9, 2006 (Wednesday).

Table 5. Phase Hold Information for College Station AWEGS.

	Phase 2				Phase 6			
	# of Holds	Mean Hold, Seconds	Std. Dev.	Phase Ends, #	# of Holds	Mean Hold, Seconds	Std. Dev.	Phase Ends, #
Sunday	11	2.0	0.53	536	19	1.8	0.60	474
Monday	18	2.2	0.71	874	27	1.8	0.57	812
Tuesday	14	2.2	0.91	711	18	1.9	0.74	673
Wednesday	8	1.9	0.63	715	16	2.1	0.62	674
Thursday	12	1.7	0.43	858	20	1.9	0.56	790
Friday	24	2.0	0.60	876	29	1.9	0.60	807
Saturday	12	2.1	0.93	642	18	1.9	0.55	552
Average	14	2.0	0.68	745	21	1.9	0.61	683

As can be clearly seen from Table 5, an average of 745 and 683 phase terminations are occurring for Phase 2 and Phase 6, respectively. During these phase terminations, an average of 14 (1.8 percent) and 21 (3 percent) phase holds are being placed by AWEGS throughout the day. The average phase hold is approximately 2 seconds. Hence, AWEGS is not having a significant impact on the controller operations. A phase hold is typically placed for the following reasons:

- A vehicle on the major arterial phases is in its dilemma zone.
- No vehicle is on the dilemma zone detectors.
- The dilemma zone detectors have gapped out.
- A vehicle shows up on a conflicting phase.

Not placing a hold will allow the controller to gap out, resulting in a vehicle being caught in its dilemma zone. However, placing too many phase holds and of a long duration can result in sluggish intersection operations. The placement of phase holds by AWEGS is not having a negative impact on intersection operations.

False Flashes

False flashes occur when AWEGS detects a vehicle on a conflicting phase that needs to be serviced and starts flashing the beacons when the algorithm predicts that the phase will terminate. However, many times after AWEGS starts flashing the beacons, the vehicle leaves the detection area and the main street phase does not terminate. AWEGS then has to terminate the false flash at a safe and appropriate time. It is to be expected that when the algorithm is predicting the behavior of the controller, the algorithm will be inaccurate sometimes. However, having a large number of false flashes is undesirable for motorists. Hence, some adjustments were made to minimize the false flashes.

TTI researchers observed the AWEGS operation for a few days and adjusted the delays on some phases. The number of false flashes in Phase 2 is significantly greater than the false flashes in Phase 6. This is because the left-turn traffic in Phase 1 is much higher than the left-turn traffic in Phase 5. As is seen in the intersection layout in Figure 11, traffic in Phase 1 is entering the Texas A&M University campus and has traffic throughout the day. Phase 5 has high traffic primary during the peak periods. The same explanation is verified when the flash numbers are compared for the weekend and weekdays. The Sunday and Saturday numbers are higher than the weekday numbers. This is because traffic is lighter in Phase 2 and Phase 6 during the weekends, resulting in more gaps being available for the left-turn vehicles to turn. It is also seen from Table 6 that the overall number of flashes per day is minimal.

Table 6. False Flashes at the AWEGS Location.

	Arterial Call		**Side-Street Call**	
	Phase 2	Phase 6	Phase 2	Phase 6
Sunday	38	3	11	11
Monday	22	3	11	15
Tuesday	30	6	10	15
Wednesday	23	4	9	11
Thursday	30	8	9	15
Friday	27	4	9	16
Saturday	38	2	6	7
Average	30	4	9	13

Advance Warning

The duration of advance warning is the primary criterion to evaluate the functionality of the advance warning system. The uniqueness of AWEGS compared to the other AWF systems is that the advance warning being provided is not of a fixed duration. It depends on the existing traffic conditions. While the ideal warning time is between 5 to 7 seconds, it can either be lower or higher. It can be lower when there is no traffic or only one or two vehicles on the main-street approach when a vehicle arrives on a conflicting phase. On the other hand the duration of the advance warning is higher when the traffic is much higher on the arterial approaches.

Subsequent to AWEGS deployment in College Station, TTI researchers observed the advance warning pattern and tried numerous strategies to keep the advance warning as consistent as possible. While the advance warning was appropriate a significant portion of time, TTI researchers observed that the advance warning seemed to be of a long duration a number of times during the day. Specifically, the advance warning was very long during the peak periods. The advance warning was also sometimes long during the peak periods. The data being logged were collected and then analyzed. Similar to the summary for the number of holds and false flashes, one week's worth of data was analyzed and is presented in Table 7. Table 7 illustrates the minimum advance warning, maximum advance warning, average advance warning, number of times zero advance warning was provided, the 85th percentile advance warning, and the 95th percentile advance warning. Table 7 also illustrates the total daily volumes for each phase for the entire week.

TTI researchers also analyzed the advance warning times and generated a frequency distribution of the advance warning duration. Figure 16 and Figure 17 illustrate the distribution of the advance warning for a Sunday and Monday, respectively.

A number of observations can be made from Table 7:

- The maximum advance warning for each day is a very high value. While this is undesirable, it is acceptable if it happens occasionally.
- The average advance warning is under 6 seconds for the weekends and between 6.7 to 8.6 seconds for the weekdays. The 85th percentile warning is less than 10 seconds for weekends and greater than 10 seconds for weekdays. Similarly the 95th percentile advance warnings are also illustrated.
- There were very few cases where the advance warning was zero seconds. Most likely these situations happened because there were no vehicles on the arterial approach when a vehicle arrived on a conflicting phase.
- The volumes are lower for weekends when compared to weekdays.

Table 7. Advance Warning Statistics for the College Station Location.

		Minimum Warning (Seconds)	Maximum Warning (Seconds)	Average Warning (Seconds)	Zero Warning	85 Percentile Warning (Seconds)	95 Percentile Warning (Seconds)	Daily Volume (Vehicles)
Sunday	Phase 2	0	57.2	5.4	4	7.4	15.0	6,345
	Phase 6	0	57.2	5.9	3	8.5	15.9	8,172
Monday	Phase 2	0	57.2	6.7	6	10.6	20.1	10,772
	Phase 6	0	57.2	7.0	5	11.1	20.6	11,588
Tuesday	Phase 2	0	62.4	7.5	4	12.6	22.0	12,107
	Phase 6	0	65.9	8.0	2	13.5	25.1	13,044
Wednesday	Phase 2	0	64.0	8.4	1	13.8	30.2	11,283
	Phase 6	0	64.0	8.6	2	15.1	32.3	12,333
Thursday	Phase 2	0	56.6	7.5	4	12.7	24.1	11,959
	Phase 6	0	56.6	8.0	2	13.5	26.4	12,504
Friday	Phase 2	0	62.7	7.4	2	11.8	22.0	12,107
	Phase 6	0	62.7	7.6	2	12.1	23.1	13,044
Saturday	Phase 2	0	43.6	5.3	1	7.5	14.1	7,839
	Phase 6	0	43.6	5.6	1	8.3	16.0	9,354
Average	Phase 2	0	57.7	6.9	3	10.9	21.1	10,345
	Phase 6	0	58.2	7.2	2	11.7	22.8	11,434

From the graphs, it is clearly seen that a significant number of advance warning durations lie between 2 to 3 seconds and between 4 and 7 seconds. The spike in the warning durations of between 2 and 3 seconds is primarily due to the delay of 2 seconds that is programmed into the controller for the side-street phases. This basically means that for a majority of the warnings of this duration, there were no vehicles on the arterial streets when a vehicle arrived on the side street. These vehicles were immediately seen by AWEGS, and the algorithm started flashing the beacons. Due to the 2-second delay, the controller saw the vehicle after 2 seconds and immediately gapped out the arterial street phase. If these warning times are taken out, the majority of the warning durations are between 4 and 7 seconds, which is close to the objective.

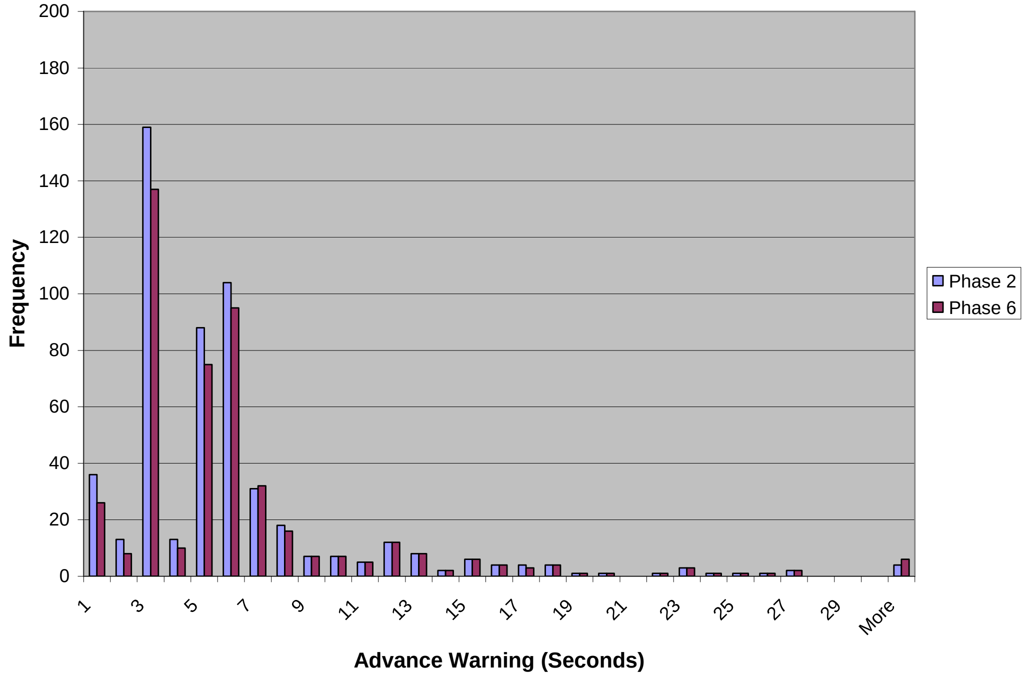


Figure 16. Advance Warning Distribution (Sunday).

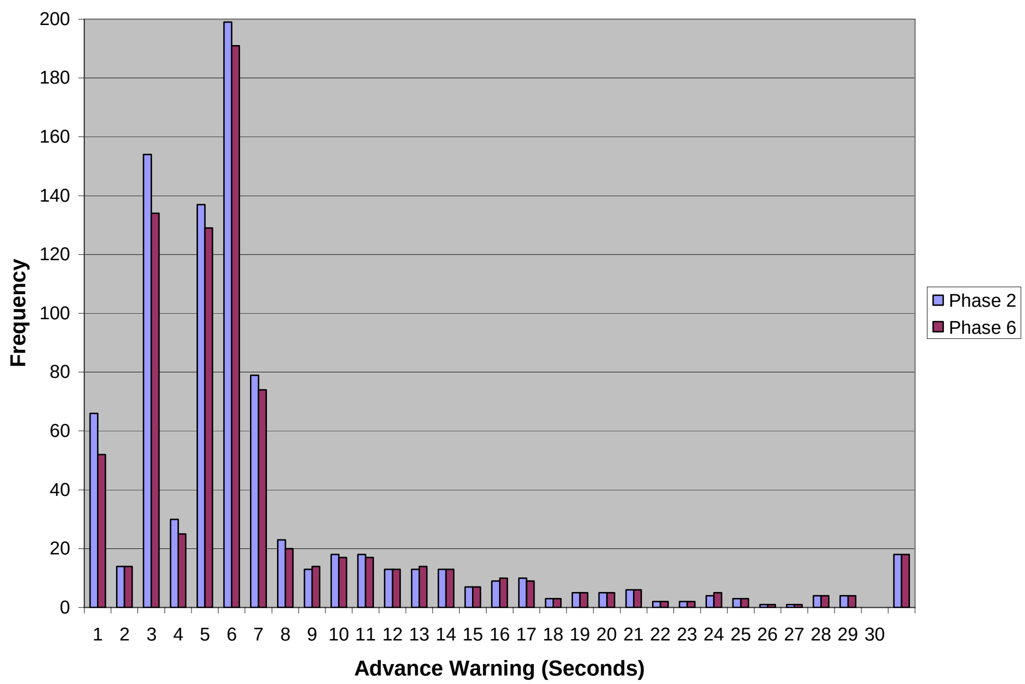


Figure 17. Advance Warning Distribution (Monday).

As seen in Table 7, the total daily volume has an impact on the duration of the advance warning. The advance warning tends to get longer than anticipated when AWEGS predicts that the controller will gap out, it starts flashing the beacons, vehicles arrive on the dilemma zone detectors, and the vehicles prevent the controller from gapping out. Such a scenario is described below:

- A vehicle (Vehicle A) arrives on a conflicting phase (side street) when a vehicle is on the furthest dilemma zone detectors (T = 0 seconds).
- Vehicle A is traveling at 55 mph, the spacing between the dilemma zone detectors is 100 feet (60 mph), and the passage time is 2 seconds.
- There are no vehicles between the advance detectors (900 feet and 870 feet) on either approach.
- Vehicle A would extend the phase by 2 seconds but take 1.3 seconds to get to the second dilemma zone detector. It would extend the phase again by 2 seconds but take an additional 1.3 seconds to get to the third dilemma zone detector. It would then extend the phase by 2 more seconds. Hence, the phase is totally extended by 4.6 seconds (T = 4.6 seconds), and the controller would gap out if no more vehicles showed up on the dilemma zone detectors.
- Hence, AWEGS decides to start flashing the beacons at T = 0 seconds.
- However, just after the beacons start flashing, another vehicle (Vehicle 2) arrives on the first advance detector (T = 0.1 seconds) traveling at 65 mph. Vehicle 2 leaves the second advance detector at T = 0.4 seconds.
- Vehicle 2 arrives at the first dilemma zone detector at T = 4.6 seconds and then extends the phase. Vehicle 2 can extend the phase until T = 8.8 seconds and thus increases the duration of the advance warning time if no other vehicles show up on the dilemma zone detectors on either approach by T = 8.8 seconds.

The above described scenario is just an example of the numerous ways the advance warning duration can increase. This is directly related to the traffic volumes on the approach. As approach volumes increase, it is likely that the advance warning duration will increase. This factor should be considered in the decision to install an AWEGS at a new location.

Traffic Performance

AWEGS was designed to reduce red-light running and to improve the resulting traffic safety. The methodology developed in the earlier AWEGS project (*3*) was adopted for estimating the red-light runners at the new AWEGS location.

Method of Data Collection

The red-light running problem before the installation of AWEGS was measured by means of surrogate methods at the FM 2818 and George Bush Drive intersection in College Station. This was done by means of a computer program that logged in actuations of detectors in the field. AWEGS collected some of the events it monitored and also the decisions it made, based on these events, into log files for system verification and evaluation. The collected data were written into two log files named *mmddyyyy.ada* and *mmddyyyy.vda*. The *.ada* log file documents the decisions made by the system and most of the intersection and controllers events AWEGS monitors. Thus, the passage of vehicles was identifiable in such files, which were converted into Excel files. Also, the current status of the advance warning flashers and the traffic signal itself were logged into these files. The *.ada* files were utilized to monitor the system performance of AWEGS, while the *.vda* files helped to analyze traffic performance of the system, specifically in the area of red-light running.

Events logged into the *.vda* files (for evaluating RLR) included time stamps for actuations of the loops provided by the video imaging system installed at the site. At the AWEGS location, each main-street monitored approach had one video loop. The *.vda* file also contained time stamps for the beginning of the green, yellow, all-red, and red intervals of main-street phases. Also in this *.vda* file are counts of vehicles detected by the first loop of the video loop pair associated with the approach, during the green, yellow, all-red, and red intervals of the main-street phases. A standard video detection system located at the intersection was used. An example of this video detection system mounted on the mast arm above the luminaire in College Station is shown in Figure 18.

Development of Red-Light Running Criteria

For two weeks prior to the installation of AWEGS, red-light running data were collected and reduced to obtain the number of red-light runners for each day. A plot of the actuations of passage times of vehicles was made to determine the nature of the distribution of these data in order to determine an appropriate range of passage times on detectors and to distinguish between a high-speed vehicle going across the intersection during a red signal from some other event. These other events included vehicles from the cross street that actuate the second video detector and any opposing left-turn vehicles that may trigger an actuation from the first detector.

Based on these plots, the researchers realized that about 80 percent of detection presence times were between 200 and 600 milliseconds. Red-light running constitutes a traffic violation that occurs when a motorist enters an intersection (often deliberately) sometime after the signal light has turned red. Motorists who inadvertently enter an intersection when the signal changes to red when waiting to turn, for example, are not red-light runners. A defined period of time of 5 seconds after the start of red clearance was used to measure red-light running.

Figure 18. Installation of a Video Detection System for Evaluating Red-Light Runners.

Thus, together with the nature of the placement of video detectors and speeds of vehicles, the red-light running event was defined as follows:

- any vehicle crossing the stop bar (from the input side of the first through VIVDS detector) during red clearance; and

- any vehicle crossing the stop bar during real red following red clearance, timed from the start of real red until 5 seconds of red display had elapsed, where the initial time on this clock starts at the start of red clearance.

These conditions were used partly to separate true red-light runners from other (false) events like side-street and main-street left-turning vehicles who inadvertently trigger one of the video detectors during red. TTI researchers developed a tool to facilitate the calculation of the red-light runners, which made it possible to reduce the data.

Before and After Study Results on Red-Light Running in College Station

TTI researchers encountered numerous challenges in the collection of the before and after data. Table 4 illustrates the log of the events that took place for the installation as well as for data collection. While the before data collection began May 27, 2006, unexpected construction activity (resurfacing of the pavement) had an impact on the data being logged. Also on a few days, the AWEGS shadow mode was interrupted for some fine-tuning or data collection. Hence, even though AWEGS was turned on June 27, 2006, TTI researchers could only collect a week of good before data (a week comprising all days of the week).

Similar challenges were encountered in obtaining a good quantity of after data. The construction activity as well as special events at this intersection in the month of July did not permit researchers to collect clean data for a significant number of days. The university's fire training school attracts a large number of attendees in the month of July, and the police department frequently operates this intersection in a manual mode. The data that were logged were analyzed to identify good data. The before data and after data used to compare the red-light running are illustrated in Table 8. The comparison of the red-light running is illustrated in Table 9.

Table 9 illustrates the number of red-light runners for each approach and shows a reduction of about 60 percent in RLR for Phase 2 and 44 percent for Phase 6. This results in a total reduction of about 51 percent in RLR for the intersection. The reductions in RLR in before and after studies are statistically and practically significant. These results show the potential benefits to be expected in a wider deployment of AWEGS where needed.

Table 8. Dates for the Red-Light Running Analysis.

	Before Data	After Data
Sunday	June 11, 2006	August 6, 2006
Monday	June 5, 2006	August 7, 2006
Tuesday	June 6, 2006	August 8, 2006
Wednesday	June 14, 2006	August 9, 2006
Thursday	June 8, 2006	August 3, 2006
Friday	June 9, 2006	August 4, 2006
Saturday	June 10, 2006	August 5, 2006

Table 9. Comparison of Red-Light Running at College Station AWEGS Location.

	Before			**After**		
	Phase 2	Phase 6	**Total**	Phase 2	Phase 6	**Total**
Sunday	14	21	35	5	18	23
Monday	29	68	97	12	23	35
Tuesday	39	34	73	20	25	45
Wednesday	34	60	94	17	37	54
Thursday	42	57	99	12	43	55
Friday	57	61	118	17	16	33
Saturday	15	18	33	6	15	21
Average	32.9	45.6	78.4	12.7	25.3	38.0
Reduction				61.3%	44.5%	51.5%

CONCLUSIONS AND RECOMMENDATIONS

The objective of this project was to make improvements to the AWEGS algorithm as well as the implementation procedures. These improvements were implemented at the existing AWEGS locations, and the improved algorithm was implemented at a new location.

AWEGS Improvements

The specific improvements to be made are:

- reduce false actuation,
- improve truck treatment,
- improve the AWEGS sign visibility,
- correct detector failure,
- improve queue detection and treatment, and
- improve the AWEGS interface.

TTI researchers recommended procedures to reduce false actuations. Reducing false actuations can initiate the beacons flashing for no reason. These procedures include parameter changes in the signal controller, use of a better video detection system, or a newer stop-bar detector configuration. The existing truck treatment was evaluated. However, significant changes were not made because the existing procedures were deemed adequate. Any modification could result in AWEGS, as well as the intersection, operating in an inefficient manner. To improve the visibility of the AWEGS sign, an overhead sign was designed. To improve the attention value, a newer pattern of flash known as stutter flash was developed and implemented. The overhead sign with the stutter flash was implemented on one approach in Brenham and on both approaches at the new AWEGS location in College Station. The new AWEGS sign configuration has significantly improved the sign visibility. While it is recommended to implement the stutter flash at all AWEGS locations, the use of an overhead sign depends on local conditions. It may not be necessary to use an overhead sign on single-lane approaches. On two-lane approaches, an overhead sign becomes essential if it is not possible to install a second roadside-mounted sign in the median. Other factors that can influence the decision are high approach speeds and the presence of any horizontal or vertical curves on the approach. Use of an overhead sign under such situations can improve the visibility of the AWEGS sign.

The algorithm was modified to function satisfactorily even if one of the advance detectors fails, if both detectors fail, or when the dilemma zone detectors fail. AWEGS operation will be close to the Level 1 AWEGS deployed in Waco during the development of AWEGS (*3*). The researchers also started using the stop-bar detectors on the arterial approaches to determine the presence of a queue and continue to flash the beacons until the dissipation of the queue. Such an application would again be useful on approaches with horizontal and/or vertical curves, which could impede the visibility of a queue. This is an optional feature in AWEGS and has been deployed in Waco. Other locations do not have stop-bar detectors, and hence this feature was not turned on. Finally the AWEGS interface was significantly improved so that the user has very few details to enter to set up AWEGS at a new location. Some of the advance input parameters were shadowed so that they cannot be changed accidentally.

Simultaneous Gap-Out Feature

Some modifications were made to the algorithm after the deployment of AWEGS in College Station. As mentioned earlier, TTI researchers observed that the warning time being provided by AWEGS was higher than at other locations. One of the important changes made was the ability to predict the probability of a phase simultaneously gapping out on both approaches. This change is similar to the simultaneous gap-out feature in the signal controller. The original algorithm was used to evaluate both the approaches for potentially gapping out. If the algorithm estimated that one approach had gapped out, it would not evaluate this approach again. The algorithm would then only evaluate the other approach. This operation is similar to having the simultaneous gap-out feature turned off. However, if the controller had the simultaneous gap-out feature turned on, this condition could result in the controller not gapping out after the AWEGS algorithm predicts that it will gap out. This could result in long advance warning durations. TTI researchers made a significant change in the algorithm so that the algorithm would function more like the simultaneous gap out turned on rather than turned off. However, even after this modification the advance warning times at the College Station location were higher than expected. TTI researchers felt that the high volumes at the College Station location were responsible for such warning patterns. TTI researchers evaluated this assumption by comparing the volumes and warning times with those at other AWEGS locations. Figure 19 illustrates the ADT at AWEGS locations for a week. The volumes at the sites in College Station and Brenham are significantly higher than the volumes in Waco and Lubbock. The Lubbock volumes are below 10,000, Waco slightly over 10,000, and College Station and Brenham over 20,000. College Station volumes are higher during the weekdays, and the Brenham volumes are higher during the weekends. These volume comparisons confirm the assumption of the TTI researchers.

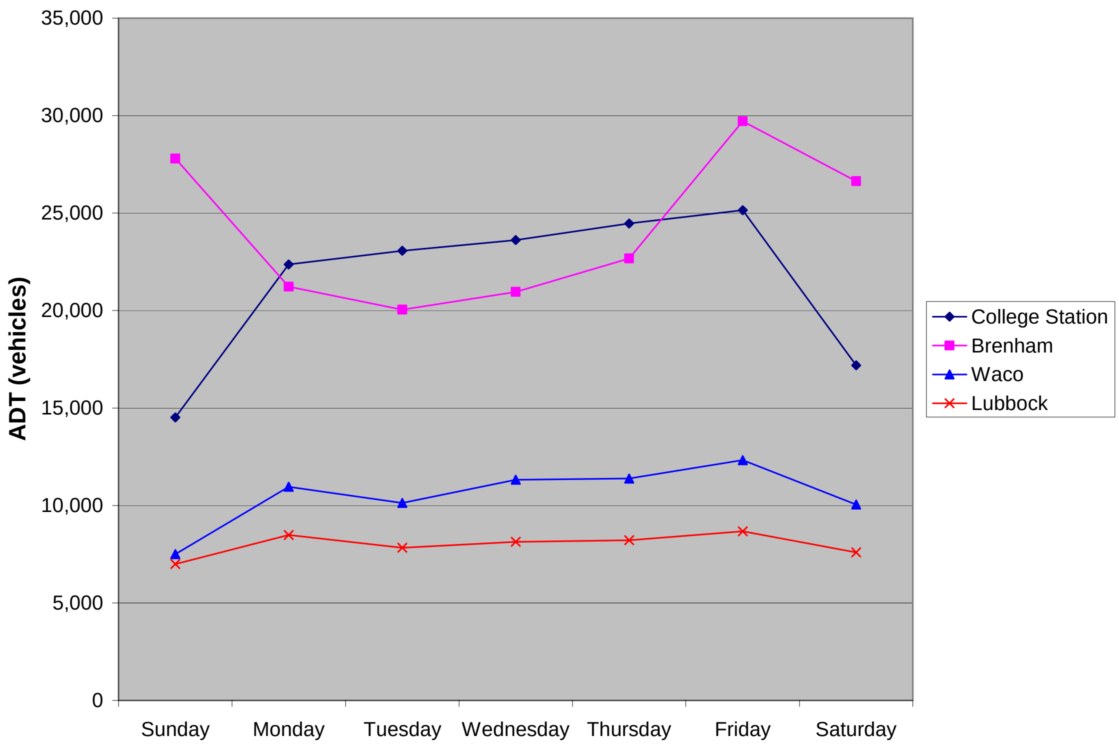


Figure 19. Comparison of ADT Volumes at AWEGS Locations.

To obtain further confirmation, the warning data from Waco were analyzed and are illustrated in Table 10. The Waco site was selected because the detector configuration and the parameters in Waco and College Station are very similar. The average warning in Waco is about 4.7 seconds, the 85th percentile is about 6.5 seconds, and the 95th percentile is about 12.5 seconds. Thus, for the AWEGS algorithm that is configured similarly at the two locations, the location with higher volumes is demonstrating much higher warning times.

AWEGS has shown that it improves safety at high-speed intersections. All the AWEGS locations have demonstrated a significant reduction in red-light running. However, AWEGS locations should be analyzed beforehand so that the algorithm performance is optimum. If a location with high volumes is selected, the operator should expect to observe higher than normal warning times. An installation and maintenance guidelines document was prepared to assist engineers and technicians in the installation, operation, and maintenance of AWEGS and is included in this report as the appendix.

Table 10. Advance Warning Statistics for the Waco Site.

		Minimum Warning (Seconds)	Maximum Warning (Seconds)	Average Warning (Seconds)	Zero Warning	85th Percentile Warning (Seconds)	95th Percentile Warning (Seconds)	Daily Volume (Vehicles)
Sunday	Phase 2	0.3	30.2	4.5	0	6.1	10.5	3640
	Phase 6	0.0	36.6	4.6	1	6.2	11.2	4931
Monday	Phase 2	0.0	35.6	4.4	2	6.1	10.8	3450
	Phase 6	0.0	35.6	4.4	1	6.1	11.2	4751
Tuesday	Phase 2	0.0	48.2	5.0	4	6.6	13.7	4202
	Phase 6	0.0	39.1	5.0	3	6.8	14.1	6937
Wednesday	Phase 2	0.0	41.3	5.0	2	6.7	13.6	4240
	Phase 6	0.0	38.4	5.0	1	6.9	14.2	6953
Thursday	Phase 2	0.0	42.3	4.9	1	6.6	12.3	4251
	Phase 6	0.0	42.3	4.8	1	6.4	12.0	7121
Friday	Phase 2	0.0	40.7	5.1	4	6.8	13.6	4343
	Phase 6	0.3	42.3	5.1	0	7.1	14.3	7741
Saturday	Phase 2	0.0	37.5	4.2	3	5.9	9.7	3926
	Phase 6	0.3	36.9	4.4	0	6.1	11.0	6022
Average	Phase 2	0.0	39.4	4.7	2	6.4	12.0	4,007
	Phase 6	0.1	38.8	4.8	1	6.5	12.6	6,351

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APPENDIX

PRODUCT 1—AWEGS INSTALLATION AND MAINTENANCE GUIDELINES FOR ENGINEERS AND TECHNICIANS

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AWEGS

AWEGS is a dilemma zone protection system designed to minimize vehicles from being trapped in their respective dilemma zones at the onset of yellow (*1*). The objective is achieved by providing advance warning to motorists approaching the intersection with the help of advance warning signs coupled with flashing beacons. Advance warning about the end of green is provided by the activation of the beacons on the warning sign. Figure 1 illustrates the functionality and the various components of AWEGS.

Typically dilemma zone detection is provided on high-speed approaches to minimize vehicles caught in their dilemma zone at the onset of the yellow indication in the traffic signal. However dilemma zone detection is typically designed to protect passenger cars up to the 85 percent approach speed. This means that passengers above the 85th percentile approach speed and trucks are not provided the same level of dilemma zone protection. The objective of AWEGS is to provide protection to trucks and passenger cars up to the 99th percentile approach speeds. Figure 2 illustrates the typical approach layout of AWEGS.

AWEGS is typically applicable at locations that meet the following characteristics:

- High-speed approaches should have a speed limit of 55 mph or greater.
- The intersection should have existing dilemma zone detection that conforms to TxDOT's practice.
- The intersection should be operating in a fully actuated mode.
- The intersection should have detection for all non-arterial phases (arterial left turns and cross streets), preferably at the stop bar.
- The location should have an ADT of not greater than 20,000 vehicles.
- There should be minimum driveways between the intersection and the advance detectors.
- The percentage of turning traffic at the intersection should not be very high.
- The location should have either a TS1 cabinet or a TS2 cabinet with a TS2-TS1 conversion panel.
- The location should have a loop input panel to monitor the detectors at the intersection.

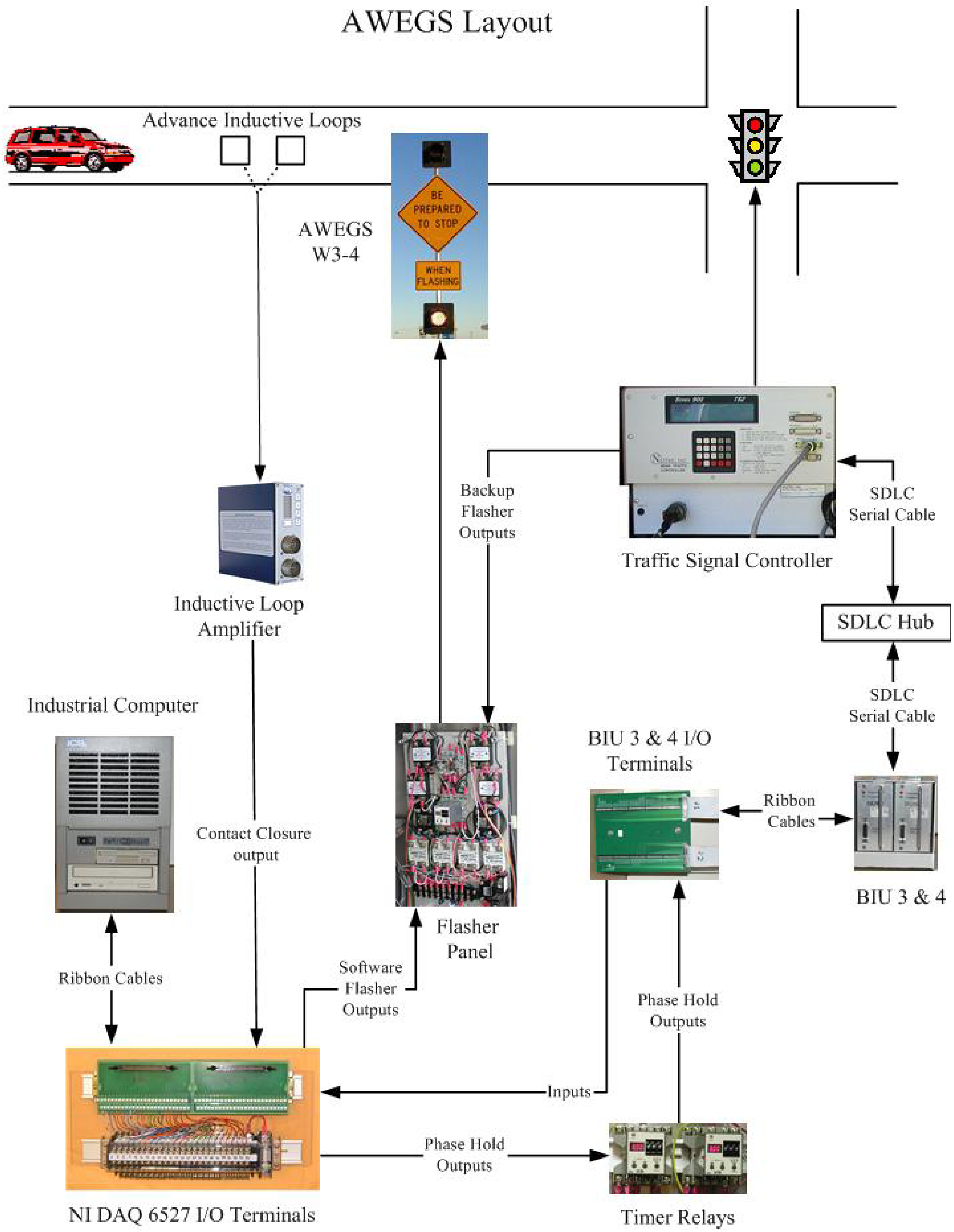


Figure 1. Layout of Advance Warning for End-of-Green System (AWEGS).

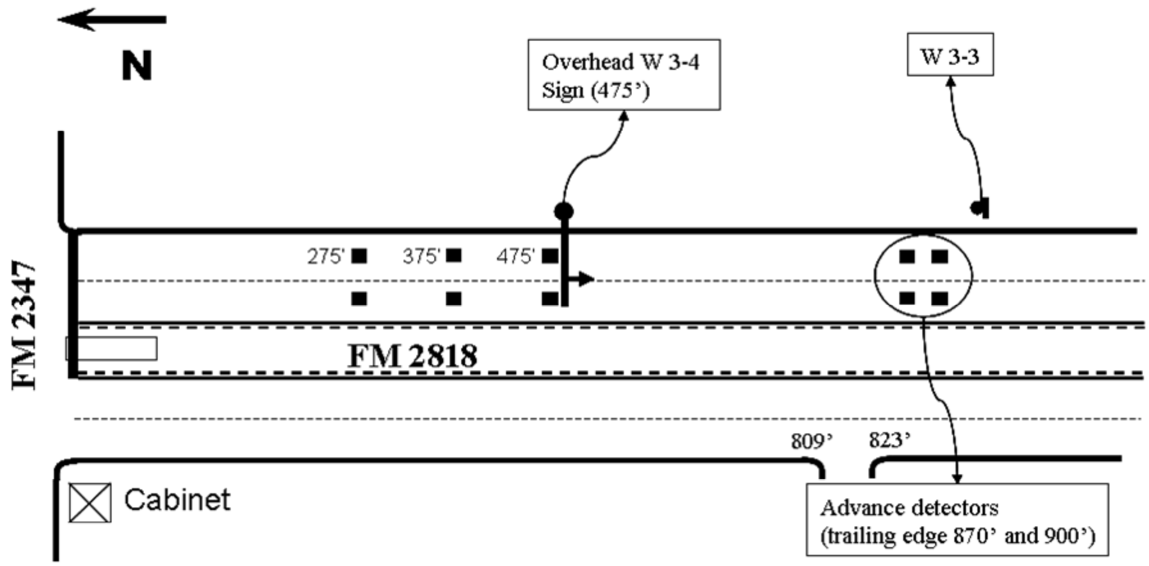


Figure 2. Typical Layout for an Intersection Approach Having AWEGS.

- It would also be desirable to have extra inputs in the detector card rack so that rack-mounted amplifiers can be installed for the advance detectors instead of shelf-mounted amplifiers. AWEGS requires two advance detectors per approach lane.

COMPONENTS OF AWEGS

Advance Warning Signs (W3-3 and W3-4)

As mentioned earlier, AWEGS functions by flashing beacons on an advance warning sign also known as a W3-4 sign. The W3-4 Advance Traffic Control sign (see Section 2C.26 of the 2000 *MUTCD*) (*2*) will be supplemented by warning beacons. The configuration of the W3-4 sign depends on the approach to the intersection and is as follows:

- single-lane approach—one roadside-mounted W3-4 sign (Figure 3),
- two-lane approach with a wide median where a roadside sign can be installed—two roadside-mounted W3-4 signs on either side of the approach (Figure 4), or
- two-lane approach with visibility limitations or a small median where a roadside sign cannot be installed—an overhead-mounted W3-4 sign (Figure 5).

Figure 3. AWEGS Sign on a Single-Lane Approach.

Figure 4. AWEGS Signs on a Two-Lane Approach.

Figure 5. Overhead AWEGS Sign.

The TxDOT's new *Sign Crew Field Book* (*3*) and the relevant sections in the *Texas MUTCD* (*4*) and national *MUTCD* (*2*) should always be consulted for official design requirements and guidance. All aspects of the signs noted in this section are in compliance with the 2000 *MUTCD* (*2*).

The configuration of the beacons on the W3-4 sign depends on the configuration of the beacons on the Signal Ahead sign (Figure 6). According to the *MUTCD*, all intersections with a W3-4 sign shall have a Signal Ahead sign, also known as a W3-3 sign. In some cases the W3-3 sign will have beacons installed as illustrated in Figure 7. If the W3-3 sign does not have beacons, it is recommended to have top-bottom beacon configuration on the W3-4 sign (Figure 3). On the other hand if the W3-3 sign has beacons, the W3-4 sign can have beacons as configured in Figure 8.

Figure 6. Signal Ahead Sign (W3-3) without Beacons.

Figure 7. Signal Ahead Sign (W3-3) with Beacons.

Figure 8. AWEGS Sign with the Beacons on Top.

TxDOT's regulation about operation of flashing beacons is as follows:

- Top-bottom arrangement of beacons on a roadside-mounted sign:
  - W3-4 beacons flashing alternating or
  - top beacon flashing before the bottom beacon.
- Top-top arrangement of beacons on a roadside-mounted sign:
  - W3-4 beacons flashing simultaneous,
  - W3-3 beacons having alternating flash and flashing *only* when the W3-4 beacons are flashing, or
  - the top beacon of the W3-3 flashing first simultaneously with the beacons on the W3-4 sign.
- Overhead sign:
  - W3-4 beacons mounted horizontally,
  - W3-4 beacons flashing alternating,
  - the left beacon flashing before the right beacon, or

- the top beacon of the W3-3 flashing simultaneously with the left beacons on the W3-4 overhead sign.

The top-bottom beacon flash arrangement tends to have a higher attention value than the top-top arrangement of beacon flash and is the preferred configuration. However, if the W3-3 sign has the beacons, the top-top beacon configuration is recommended to make a distinction from the beacons on the W3-3 sign.

Sign and Beacon Specifications

Following are the specifications of the roadside-mounted sign (*5*):

- 7-inch Series D lettering on 48-inch × 48-inch high-intensity fluorescent yellow on black sheeting—BE PREPARED TO STOP;
- 6-inch Series D legend on a 36-inch × 24-inch plaque—WHEN FLASHING;
- two vertically mounted 12-inch LED flashing beacons, with assembly (RFBA-98) for a top-bottom arrangement of beacons;
- two horizontally mounted fish-eye 12-inch LED flashing beacons for top-top beacon arrangement; and
- due to local vertical curves, beacons mounted at 10 and 2 o'clock positions, with assembly (RFBA-98) for the arrangement of beacons.

Following are the specifications of the overhead-mounted sign (Figure 9):

- 8-inch Series D lettering on 48-inch × 48-inch high-intensity fluorescent yellow on black sheeting—BE PREPARED TO STOP,
- 6-inch Series D legend on a 36-inch × 24-inch plaque—WHEN FLASHING, and
- two horizontally mounted 12-inch LED flashing beacons on either side of the overhead sign.

More visually attractive advance warning signs could readily be used in AWEGS using a basic on/off switch control. An example could include overhead cantilevered electronic matrix signs, similar to the one installed in Marshall, as shown in Figure 10. This type of sign support structure would appear justified for high-speed, multilane roads having two-way left-turn lanes or no (adequate) median divider.

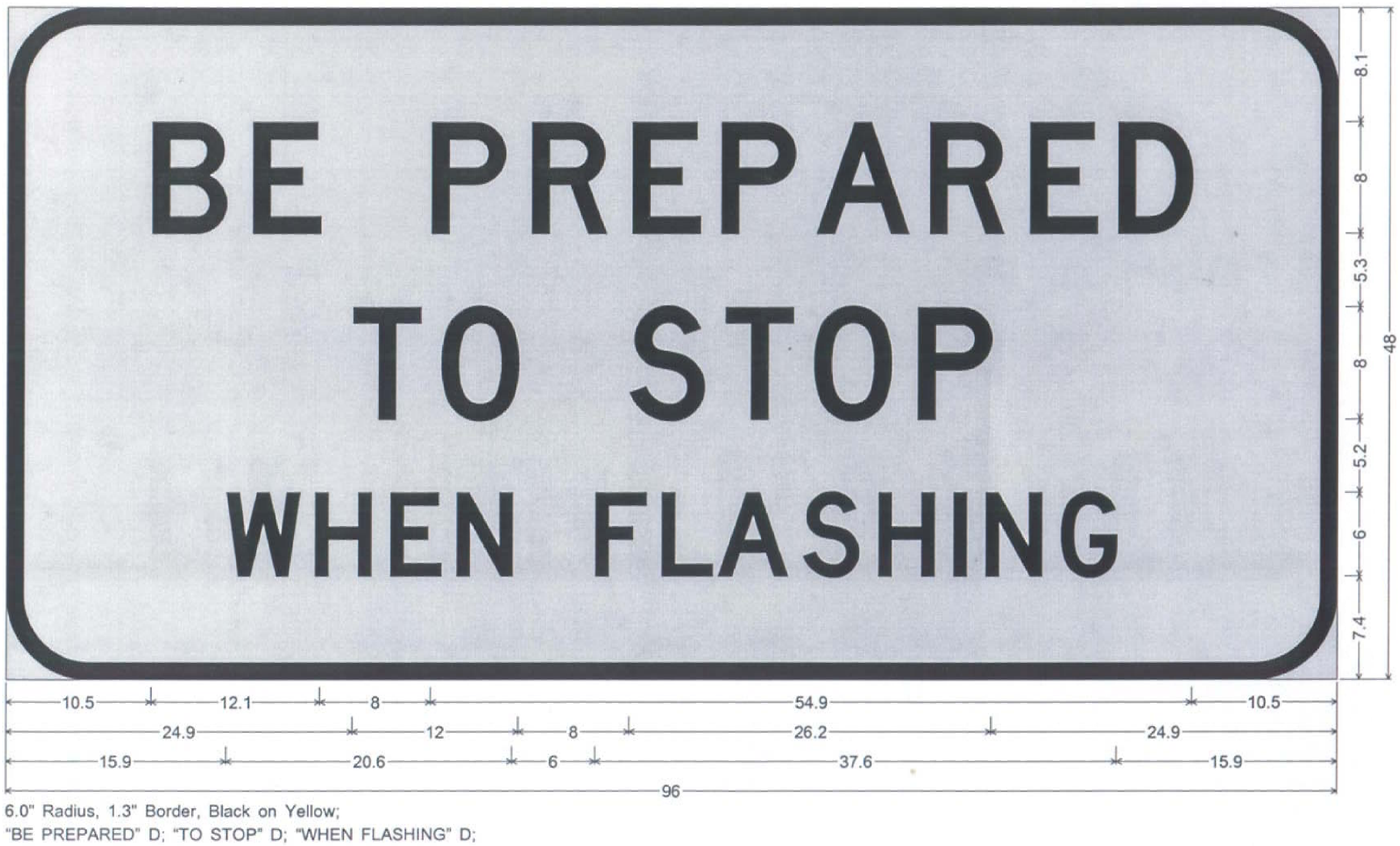


Figure 9. Dimensions of the Overhead AWEGS Sign.

Figure 10. Overhead Electronic Matrix Sign.

Sign and Beacon Location

Two AWEGS-related sign location problems need to be addressed. One is the station along the highway where the W3-4 sign is to be positioned. The second identifies the target location along the approach roadway where the flashing beacons should be targeted. The AWEGS W3-4 sign (or functionally similar sign) should be located along the roadway where the Institute of Transportation Engineers (ITE) based stopping distance to the onset of the yellow signal exists, based on serving the 85th percentile approach speed, from:

$$X_{W3-4} = 1.467 * V_{85} * T + \frac{2.151 * V_{85}^2}{2(d \pm gG)}$$

where:

X_{W3-4}	=	ITE-based stopping distance, feet;
V_{85}	=	85th percentile approach (design) speed, mph;
T	=	perception-reaction to yellow onset, 1.0 second;
d	=	maximum usual (ITE) stopping deceleration rate, 10 fps^2;
g	=	gravity, 32.2 fps^2; and
G	=	roadway grade, decimal equivalent.

Since the above stopping distance is about the same as that recommended for the leading detector (CDA 1) in Nader's guide (6), the practical location of the W3-4 sign is near the location of the first dilemma zone detector given in Nader's guide. This similarity assumes that the approach speed now existing (as determined from a spot-speed survey) is similar to the design speed used to select the detector layout from Nader's guide.

Local site adjustments of ± 50 feet to avoid driveways, etc. are considered acceptable in locating the W3-4 sign (5). The focal point of all flasher beacons for an approach is the same. The target location shall be the centerline of the approach roadway at the location of the ADA advance detector at the drivers' eye height. Field experience suggests that correctly targeting these beacons must be given high priority, and subsequent field inspection of their targeting during and after construction is imperative.

Field observations indicate that several problems may arise during installation (7). The beacons may be misaligned during initial setup, perhaps due to the approach road vertical curvature. They may later become misaligned due to temperature changes and wind-induced vibrations if their mountings are not secure. LED beacons tend to have a relatively narrow angle of view, and their apparent brightness will not be high or uniform unless they are always targeted at the same point on the approach roadway. This is especially true if two W3-4 signs are used per approach, one on each side of four-lane divided roadways as seen in Figure 11.

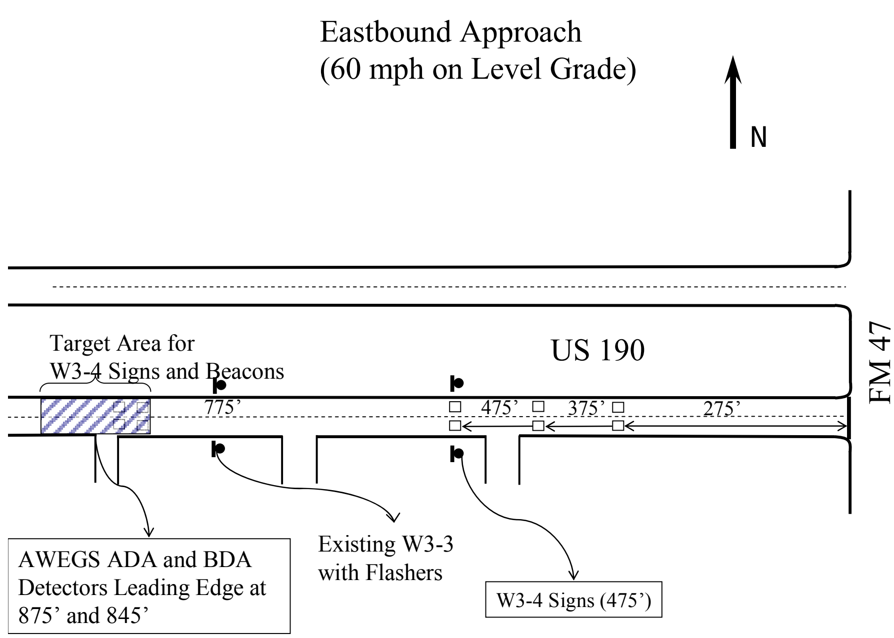


Figure 11. Location of Focus of the LEDs on the AWEGS Sign.

The electrical wiring of AWEGS W3-4 signs is relatively simple. Power is only required to drive the low-power LED flashing beacons, which is provided from the signal cabinet by the AWEGS computer/terminal switches. Thus, 120 volts alternating current (VAC) electrical power and control of the sign beacons are combined using three conductors of a five-conductor #12 AWG cable or the like. Since the sign is strategically located close to the existing dilemma zone detectors, electrical ground boxes and conduit should already be in place, which may expedite the cable run to the signal cabinet. Engineering judgment should be used to warrant any lightening arrestors for the W3-4 signs.

Advance Detectors

In AWEGS design, the two ILD speed-trap detectors in each lane are called the ADA and BDA detectors. ADA is the leading detector, and BDA is the trailing detector of the speed trap. Both detectors operate in the presence mode of detection. Both ILD detectors shall be 6-foot × 6-foot inductive loop detectors, and each loop installed on the approach *must* have an independent home run (lead-in wire) back to the cabinet. For a single-lane approach, two advance detectors and two lead-in wires will be installed. For a two-lane approach, four advance detectors and four lead-in wires will be installed. Figure 12 illustrates the configuration of the pair of loops in each lane where ADA and BDA are the names of the two loops.

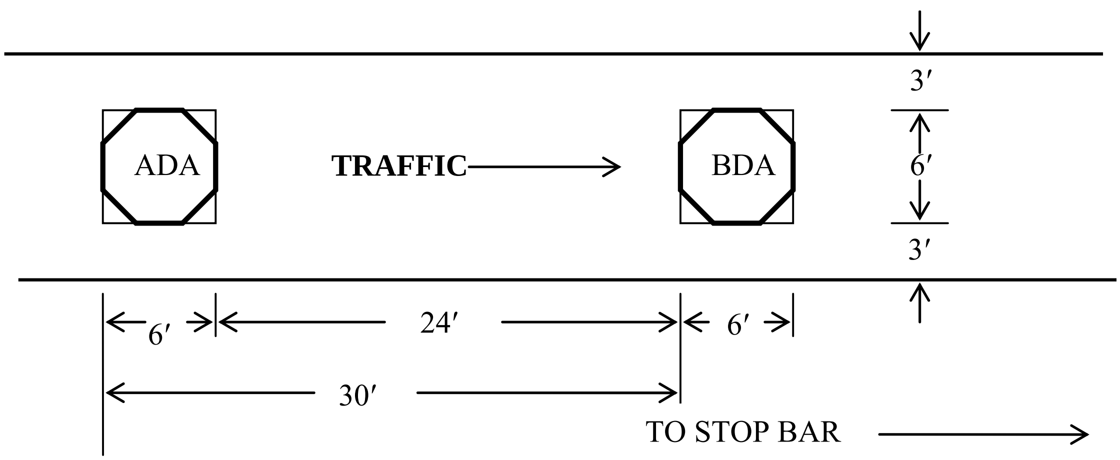


Figure 12. Advance Detector Configuration.

Two advance detectors per approach lane are added to existing signal control systems for each approach to serve three functions in AWEGS. They provide a more distant look into the future regarding the nature of arriving traffic than is typically provided (or needed) by dilemma zone detectors (Nader's guide) (*6*). They also form a well-defined speed trap to better estimate the arrival time of each and every vehicle to the first downstream dilemma zone detector. Lastly, they are used to estimate (classify) the type of vehicle into car or truck categories. Knowing the type of vehicle and its speed, AWEGS estimates their respective dilemma zones in real time (*1*).

The design, location, and construction of the advance speed-trap detectors are critical to the successful operation of AWEGS. Legacy ILD designs are currently recommended for AWEGS applications based on field experience with their operational measurement precision, dependability, and technology requirements. Wireline communication is also recommended due to its dependability, although wireless technology has been used at the AWEGS location in Lubbock successfully. Wireless technology used was based on research conducted in an earlier TxDOT project (*8*) and is providing excellent contact closure information. Long home runs (some over 1000 feet long) to the signal cabinet offer design challenges, but modern ILDs seem to have little problem working as specified when the ILD system is well designed and constructed.

Location

The leading edge of the ADA detector provides AWEGS with the first indication of the arrival of a vehicle. AWEGS begins a process of responding to this vehicle as it travels across the ADA detector and then arrives at the BDA detector. A typical travel time between these two arrival events is on the order of 0.3 seconds or so. The activation presence of the ADA detector is also monitored by AWEGS as the vehicle travels over the ADA detector. With the leading edge of the BDA detector strategically placed 30 feet downstream from the leading edge of the ADA detector, providing a 24-foot gap between them, a car will leave the ADA detector (lose its presence) before reaching the BDA detector, but a truck will still have its presence noted on the ADA detector. Thus, AWEGS can distinguish a car (ADA off, BDA on) from a truck (ADA on, BDA on) as the vehicle arrives on the BDA detector. AWEGS can also easily determine its speed. Recent federal legislation aside, trucks have more difficulty stopping than do cars. The literature suggests that the maximum acceptable deceleration rate for a truck to stop is 70 to 80 percent of that for a car (*7,9*).

AWEGS design specification provides a car with enough distance (and time) to permit the 99th percentile approach speed car to slow down to the design speed of the downstream dilemma zone detectors (CDA) at the leading edge of the first dilemma zone detector (CDA 1). Another way of saying this is that AWEGS provides the 99th percentile approach speed vehicle (car) with enough warning that it could safely stop if and when the downstream red signal is displayed, assuming ITE's base deceleration rate. An equation to calculate this location for the ADA detector is (*5*):

$$ADA = 1.467 * V_{99\%} * T_{W3-4} + \frac{2.151 * (V_{99\%}^2 - V_{85\%}^2)}{2(d \pm Gg)} + X_{W3-4}$$

where the terms are:

ADA	=	leading edge of the ADA advance warning detector, feet;
$V_{99\%}$	=	99th percentile speed $V_{99\%} = V_{85\%} + 1.3 * \sigma \cong V_{85} + 9$, mph; and
T_{W3-4}	=	input-perception-read-reaction to W3-4 flasher and decision to slow down (time is = 2.7 seconds = 0.2 seconds + 2.5 seconds).

Several factors increase the distance the ADA detector should be from the stop line. Increasing speed increases the stopping distance. Increasing downgrade to the intersection (-*G*) increases the stopping distance. Table 1 illustrates the typical location of the ADA and BDA detectors and the AWEGS sign for various speeds. As noted above, the BDA detector is located 30 feet downstream of the ADA detector. Thus, the relative location of the leading edge of the BDA detector is:

$$BDA = ADA - 30\ feet$$

Table 1. Locations of AWEGS Advance Speed-Trap Detectors and W3-4 Sign for Level Grade Using Nader's Guide for Dilemma Zone Detection.

Design or Approach Speed, mph	AWEGS ADA Detector, Feet	AWEGS BDA Detector, Feet	Sign W3-4 at CDA 1 Detector of Nader's Guide, Feet
45	595	565	330
50	683	653	350
55	776	746	415
60	875	845	475
65	979	949	540
70	1089	1059	600

PC and Cabinet

A field-hardened industrial computer is currently used to run AWEGS. The industrial computer used is manufactured by Kontron America and includes an Intel 850 MHz single-board computer, 40 gigabyte hard disk, and two National Instrument's digital I/O cards (Model #NIDAQ 6527) with 24 inputs and 24 outputs each. The NIDAQ cards are used to monitor the actuations of the advance speed-trap detectors. The NIDAQ cards are also used to monitor the status of the main-street phases, stop-bar detectors, dilemma zone detectors, and controller ring status bits (three bits: A, B, and C per ring) through contact closure connections on the signal cabinet's back panel. The large hard disk was necessary to store log files collected to evaluate and analyze the system performance during research development.

The cabinet should have enough space to install the digital input/output cards, the flasher panel, the advance detectors, and the hardened PC. The cabinet should have a loop input panel to monitor all the intersection detectors. These include the stop-bar detectors as well as the dilemma zone detectors. In some cases, the stop-bar detectors may consist of video detectors. Provision should be made for providing access to the actuations even from these video detectors. It may be desirable to have a large detector rack with all the slots enabled. This setup would call for the use of rack-mounted amplifiers for advance detectors instead of shelf-mounted amplifiers. This setup will save space, and maintenance becomes easier.

NI DAQ 6527 I/O Terminals

The NIDAQ digital input/output card mentioned above consists of six ports. The ports are numbered 0, 1, 2, 3, 4, and 5. Ports 0, 1, and 2 are input ports, and Ports 3, 4, and 5 are output ports. Each port consists of eight channels. The card provides a total of 24 input and 24 output channels. The 24 input channels are used to get the actuations of the advance detectors, intersection detectors, and phase status using the ring status bits (three bits: A, B, and C per ring) from the cabinet's back panel. Two output channels send a signal to hold the main-street phases and flash the warning signal beacons. Detailed assignment of the channels for all six ports is illustrated in Appendix A.

A bus connecting all 24 bottom-level terminals supplies all 24 16K ohm resistors with 24 volts direct current (VDC). The supply to the bus is fused by a 0.2 amp fuse to protect the output of the traffic signal controller. The current flowing through each resistor is approximately 1 milli-amps (mA) when the output from the traffic signal controller is active low on a particular output. Each input for the NIDAQ card requires 1 mA for the NIDAQ card's optical isolator's LED to work reliably. The path the current flows is from the 24 VDC supply through the fuse, through the resistor and into the NIDAQ optical isolator, and then out of the NIDAQ and into the output of the traffic signal controller. Current sinks into the output only when the output of the traffic signal controller is active low.

Loop Amplifier Specifications

TTI researchers have used and have recommended the use of Reno Model S series, two-channel loop amplifiers. If a large fully wired detector rack is available, rack-mounted amplifiers should be used. Otherwise, shelf-mounted amplifiers should be used with two cable harnesses per unit.

Flasher Panel

TTI researchers designed a flasher panel to operate the beacons on an AWEGS sign. The schematic of the flasher panel is illustrated in Figure 13. The complete fabricated flasher panel installed at all AWEGS locations is illustrated in Figure 14. An AWEGS requirement is that the flasher must always display a "full on" period within 0.2 seconds of the time the system detects a vehicle at the ADA detector. Surprisingly, the detection-response time of 0.2 seconds is not the real challenge. The real challenge is to always get the "full on" flash time. No off-the-shelf flasher could be found in the signal industry that could reliably provide this desired feature. Only expensive microprocessor-based programmable timers could be found. Thus, the AWEGS computer is used to "drive the flashers," i.e., the system uses a software flasher to get the desired initial "full on" flash.

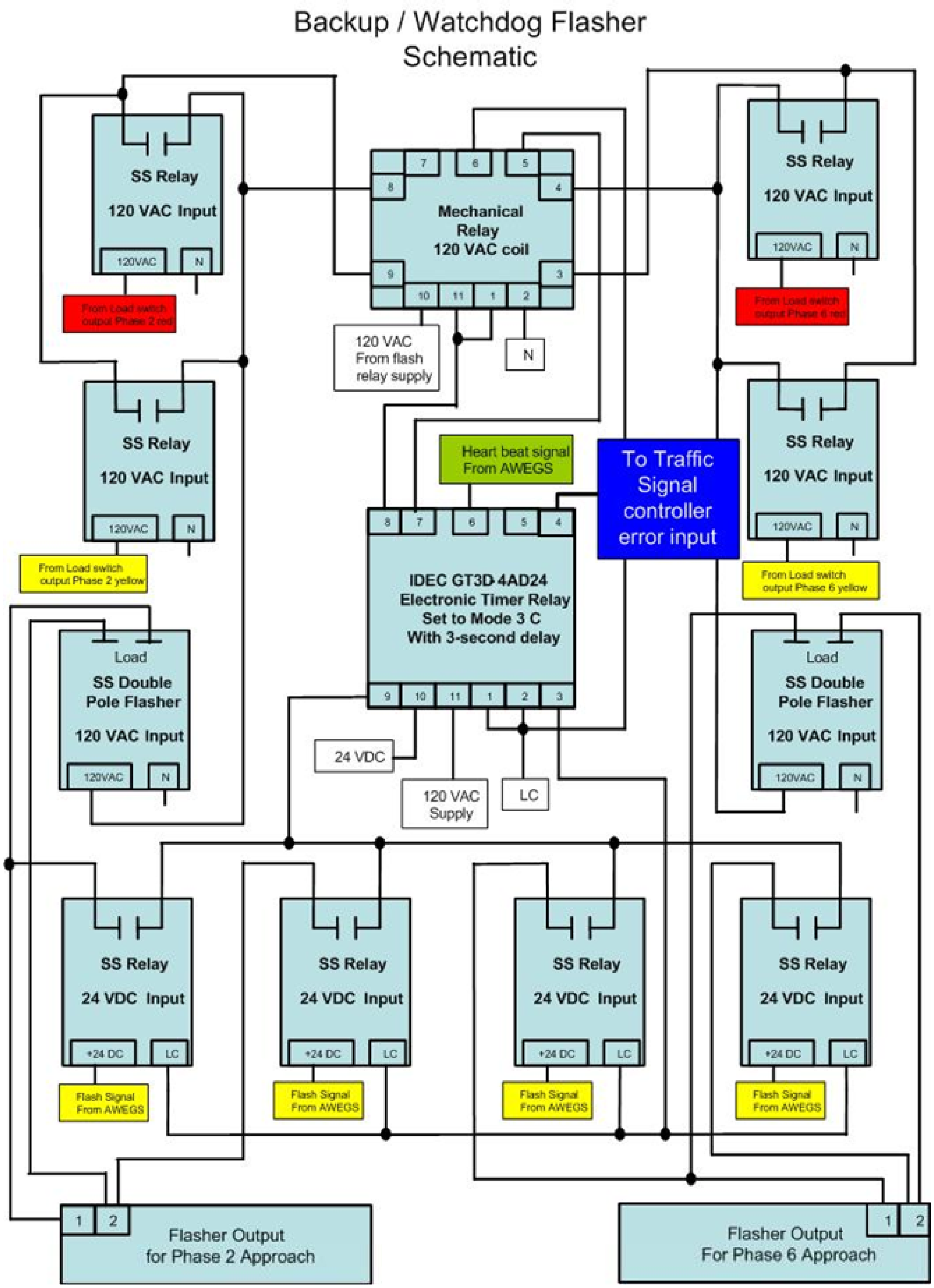


Figure 13. Flasher and Backup Panel Schematic.

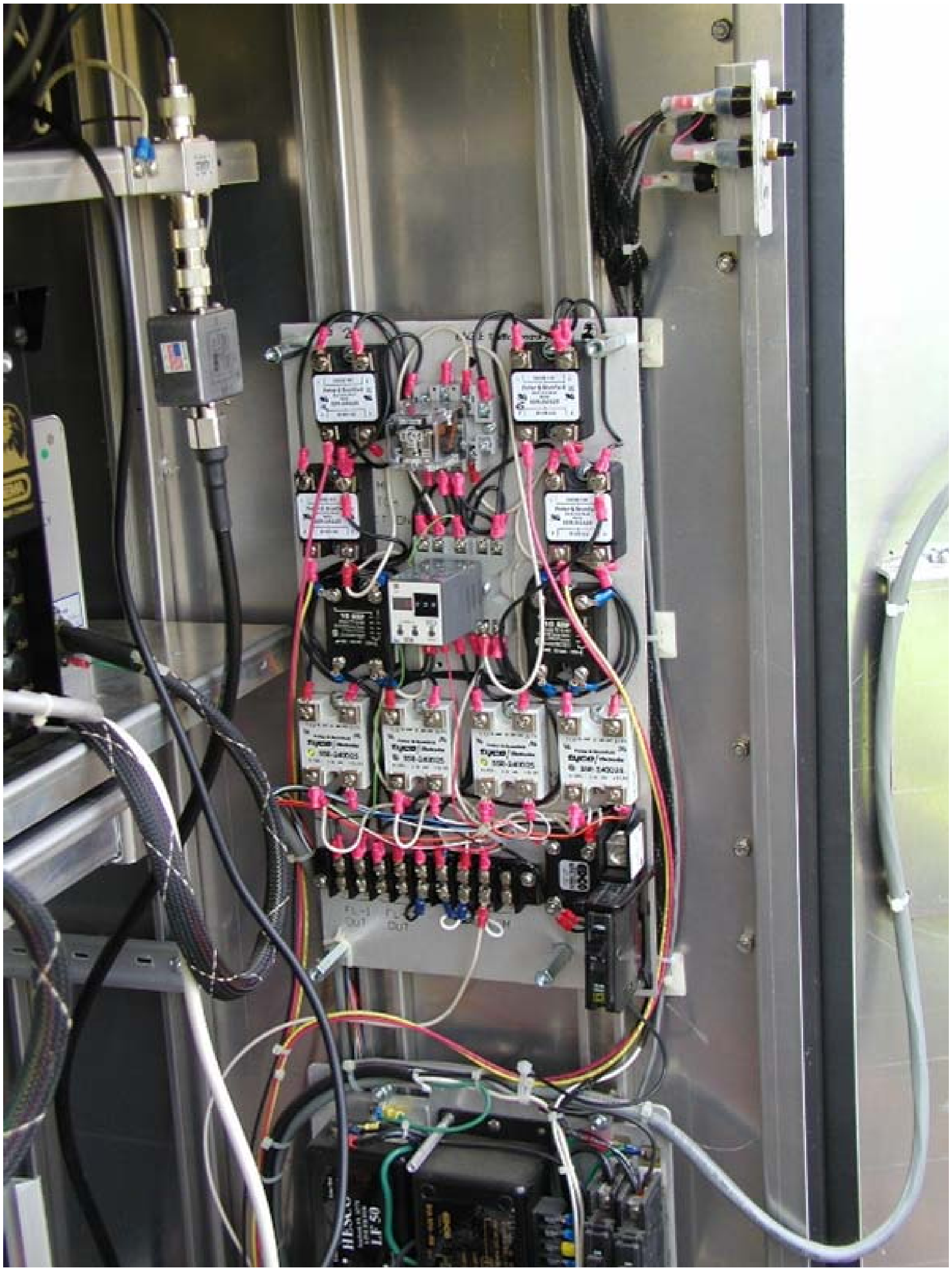


Figure 14. Flasher Panel Installed in a Cabinet.

Software Flasher System

The software flasher system uses four solid-state relays whose input signal is controlled by AWEGS. When AWEGS turns on one of the four outputs, 24 VDC is supplied to the optically isolated input of a solid-state relay, causing the output of that relay to supply 120 VAC to a particular beacon. By precisely switching the relays alternately on and off, AWEGS creates a software flasher of the desired type of flash. The software flasher was originally used with a 1-second duty cycle, with 0.50 seconds on and 0.50 seconds off. However, a new type of flash pattern called stutter flash was designed and implemented at the AWEGS locations. The objective of the development of stutter flash was to improve the attention value of the flashing beacons. Stutter flash is still experimental for warning signs. However Section 4L of the *MUTCD* (*2*) provides guidelines for the operation of the stutter flash for in-roadway warning lights. According to Section 4L.02, "The flash rate for In-Roadway Warning Lights at crosswalks shall be at least 50, but not more than 60, flash periods per minute. The flash rate shall not be between 5 and 30 flashes per second to avoid frequencies that might cause seizures." Based on the above requirements, the AWEGS computer was configured to provide a stutter flash of a 1-second cycle with the following on/off configuration:

- 0.1 second — On
- 0.1 second — Off
- 0.1 second — On
- 0.1 second — Off
- 0.1 second — On
- 0.5 seconds — Off

Local conditions may desire a flashing pattern from an alternate flashing top-bottom arrangement of beacons to a simultaneous flashing side-by-side beacon arrangement. This is accomplished by changing the wire connections on the flasher output to the beacons as seen in Figure 13. For simultaneous operation, both beacons for a particular approach are connected to flasher output 1. For alternating flashing operation, one beacon is connected to flasher output 1, and one beacon is connected to flasher output 2.

Backup/Watchdog Flasher System Logic

The flasher panel has been designed to include a watchdog functionality to monitor the heartbeat of AWEGS and provide a backup function if necessary. When AWEGS is operational, the system changes the state of output on the digital output interface every 2 seconds from high to low voltage. The heartbeat (digital output) is connected to the reset terminal of the timer relay that is set to countdown to 3 seconds. The heartbeat signal causes the timer relay to reset its countdown time back to zero whenever the state changes to low. Whenever the heartbeat is not present for 3 seconds, the timer disconnects the software flasher system and connects the backup flasher system.

During the backup flasher system, beacons on the approaches continue flashing independently during the yellow and red indications of phases for those approaches. The optically isolated inputs of the four 120 VAC input solid-state relays constantly monitor the status of the load switches for the yellow or red indications of those phases. When the backup system is activated, the timer relay's normally closed contact powers the 120 VAC output supply voltage of the solid-state relays monitoring the load switches. When any one of the four solid-state relay's inputs is supplied 120 VAC from a load switch, the relay supplies 120 VAC to the appropriate solid-state double pole flasher that is connected to the flasher beacon associated with that particular phase. When the heartbeat is restored, the timer relay disconnects the backup flasher system power supply and connects the AWEGS software flashers with 120 VAC power supply and logic common connection.

The backup system will also flash the beacons when the cabinet is in cabinet flash, when the Malfunction Management Unit (MMU) detects a malfunction, or if the power to the flash transfer relay's input is not present for any reason. The mechanical relay's 120 VAC input is supplied from the same source as the flash transfer relay's input source. When 120 VAC input is not present on the relay's input due to a fault condition or loss of power, the normally closed contacts in the mechanical relay power both solid-state two-pole flashers. The backup flasher system's control logic was created by combining the inputs and outputs of four solid-state relays with one mechanical relay and one timer relay.

Timer Relay for Phase Holds

Two electronic timer relays (IDEC GT3D-4AD24) are used to monitor the phase hold signal from AWEGS in case of a malfunction in the system. The timer relay is set to mode 3C on the operation mode selector and 8 seconds of delay on the time setting digital switch. In this mode, the relay starts counting down when a phase hold signal is applied. The phase hold signal passes through closed contacts in the timer relay. If the phase hold signal continues longer than 8 seconds, the timer relay times down from 8 seconds to zero and opens the contacts, dropping the phase hold. If the phase hold signal does not last for more than 8 seconds, then nothing happens. The relay resets back to 8 seconds whenever AWEGS drops the phase hold signal. There are two timer relays that work independently for each phase hold. Figure 15 illustrates the layout of the timer relay for phase holds.

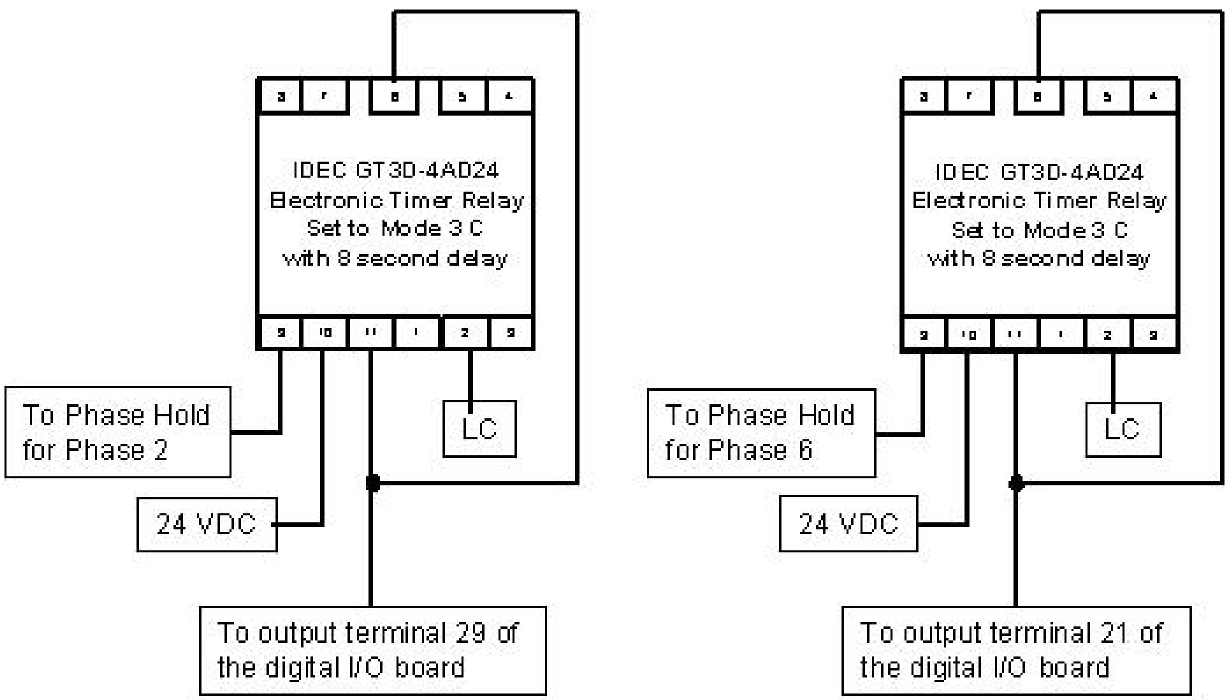


Figure 15. Timer Relay for Phase Hold.

TS-2 to TS-1 Conversion Panel

TS-2 cabinets do not have a back-panel that provides contact-closure access to phase status, detector actuations, ring status bits, and other controller inputs required by the AWEGS algorithm. TS-2 cabinets instead use a serial bus to communicate the phase status, detector actuations, and other inputs and outputs between the controller and the various modules in a TS-2 cabinet like Bus Interface Units (BIUs). In order to have contact-closure access to the various controller inputs required by the AWEGS algorithm in a TS-2 cabinet, TTI researchers ordered a TS-2 to TS-1 conversion kit from Texas Highway Products and designed by ITS Siemens. The conversion kit includes an auxiliary BIU interface panel (contact-closure panel) to provides TTI researchers access to a set of controller inputs and outputs, an auxiliary BIU rack to house BIUs 3 and 4 that contain some of the inputs required by AWEGS, two BIU 700, a connectivity assembly for 6 Synchronous Data Link Control (SDLC) cables, and other accessories like BIU rack cable, BIU rack power cable, and SDLC cables. The contact-closure panel provides TTI researchers with access to the following TS-2 controller inputs and outputs:

- Phase On status,
- Phase Next status,
- Phase Check status,
- Phase Hold, and
- Ring Status Bits (3 per ring)

The panel also has other contact-closure connections that are not used by the AWEGS algorithm like phase omits, pedestrian omits and other controller inputs and outputs.

Components Procurement Specifications

The components required for installing AWEGS at a site were procured from various vendors. This section provides details for the purchasing the various components:

Industrial PC

Model # 9301-06I

- 256NU-P133LP-815: PC133 256MB UNB LP 32MX8
- 9301-06IEMPTY: CHAS NODE 6 SLOT 300W AC
- CDW552G-KIT: TEAC CD-RW BEIGE KIT
- SBC-815ET-VE: SBC-815ET-VE
- 602-0053-00: KIT PCI B/P 9301-06I
- 6Y080L0: ATA/133 7200RPM 80GB IDE HDD
- 3-274915-1: CPU PIII 1.2GHZ/133 FCPGA(T)
- FD-1.4M: 1.44MB 3.5-inch floppy drive

Vendor

Kontron America, Inc.

Dept. 9073

Los Angeles, CA 90084-9073

Telephone: (800) 480-0044

Website: http://us.kontron.com

Number required: 1

Estimate: $2300

National Instruments Digital I/O Card

Card #: NI PCI-6527

- 24 optically isolated digital inputs (0-28 VDC)
- 24 isolated, solid-state relay digital outputs (0-60 VDC, 0-30 Vrms)
- Switch up to 120 mA

CB-50 I/O Connector Block with DIN-Rail Mounting - 776164-90
Termination accessory with 50 screw terminals for easy connection of field I/O signals to NI 6527 devices. Includes one 50-pin header for direct connection to 50-pin cables. The CB-50 includes a protective plastic base and hardware for mounting the accessory on either a standard DIN rail or flush on a wall or panel.

Vendor

National Instruments

P.O Box 840909

Dallas, TX 75284-0909

Telephone: (888) 280-7645

Website: http://www.ni.com

Number required: 2

Estimate: $1400 including 2 cards, software, and cables.

TS 2 to TS 1 Cabinet Conversion Kit

This kit consists of a panel and two BIUs in two BIU racks.

Vendor

ACM Highway Products

P.O Box 1732

Austin, TX 78680

Telephone: (512) 255-1464

Number required: 1

Estimate: $1400 including installation on site

Surge Protectors

These surge protectors are designed to protect the equipment in the cabinet from lightning surges coming in from conductors for each beacon.

Model # DS 150E

Vendor

Citel, Inc

1515 NW 167th Street, Suite 6-303

Miami, FL 33169

Telephone: (800) 248-3548

Website: http://www.citelprotection.com/citel/din_rail.htm

Number required: 4

Estimate: $500

2 Pole Flashers

These flashers serve as back up flashers and are installed on the flasher panel.

Model # TF-9-60 (60 FPM Solid State, 2 Pole Flasher).

Vendor

Electrosystems Bellingham Inc.

P.O. Box 9754

Bellingham, WA 98227

Telephone: (800).668-2254

Website: http://www.es-web.com/TFF12.html

Number required: 3 (including 1 spare)

Estimate: $180

NI-DAQ Traffic Cabinet Interface

Components illustrated in Table 2 are required for the NI-DAQ Traffic Cabinet Interface and can be purchased from an electronic component store.

Table 2. Components of a NI-DAQ Cabinet Interface.

Parts to Build NI-DAQ Traffic Cabinet Interface			
	Quantity	**Price**	**Subtotal**
Aluminum DIN Rail	1	$7.32	$7.32
Double Terminal Blocks Idec BNDH15W	24	$3.45	$82.80
Double Terminal Block End Plate Idec BND15W	1	$1.55	$1.55
Fork Terminal Jumpers Idec BNJ26FW	5	$1.79	$8.95
DIN Rail Stop Idec BNL-8	2	$4.10	$8.20
Single Terminal Blocks Idec BNH15MW	24	$1.09	$26.16
Single Terminal Block End Plate Idec BNE15W	1	$0.41	$0.41
DIN Rail Stop Idec BNL-5	2	$1.25	$2.50
Dust Cover Idec BNC230	1	$11.87	$11.87
Marking Strip Idec PVC BNM7	1	$0.99	$0.99
End Clip Idec BNM3	1	$0.30	$0.30
Fuse Holder Idec BNF10SW	1	$5.11	$5.11
End Clip Idec BNM3	1	$0.30	$0.30
1/20A fuse	1	$0.84	$0.84
10 ' of 19 pair 22 AWG wire	1	$20.00	$20.00
1 roll of 22 AWG wire	1	$5.89	$5.89
16K ohm resistors	24		$0.00
Box of red fork terminals	1	$5.00	$5.00
		Total	**$188.19**

Flasher Panel

The following parts are required to fabricate the flasher panel. These components can be procured from an electronic component store.

Table 3. Components for a Flasher Panel.

Parts of a Flasher Panel	
	Quantity
Idec GT3D-4AD24 timer relay and base	4
Potter Brumfield KRPA 14AG-120 Mechanical Relay with base	2
Potter Brumfield SSR-240A25 Solid State relay	5
Potter Brumfield SSR-240D25 Solid State relay	5
Aluminum DIN Rail	1
Double Terminal Blocks Idec BNDH15W	24
Double Terminal Block End Plate Idec BND15W	1
Fork Terminal Jumpers Idec BNJ26FW	5
DIN Rail Stop Idec BNL-8	2
Single Terminal Blocks Idec BNH15MW	24
Single Terminal Block End Plate Idec BNE15W	1
DIN Rail Stop Idec BNL-5	2
Dust Cover Idec BNC230	1
Marking Strip Idec PVC BNM7	1
End Clip Idec BNM3	1
Fuse Holder Idec BNF10SW	1
End Clip Idec BNM3	1
1/20A fuse	1
10 ' of 19 pair 22 AWG wire	1
1 roll of 22 AWG wire	1
In line fuse holders	4
5 amp fuses	4
15K ohm resistors	24
Box of red fork terminals	1

AWEGS Design and Operational guidelines

AWEGS should be designed with the best traffic and roadway data that can be obtained. In addition, an accurate inventory of the existing traffic detector layouts (e.g., from Nader's guide) must be provided. Even the type of existing signal controller, cabinet features, and signal timings must be determined. Since current AWEGS design requires the installation of a hardened industrial-grade computer, space availability in the cabinet and the quality of the cooling system are important factors that should be determined. Construction and installation of inductive loop detectors to the designated spacing and sizes are also paramount.

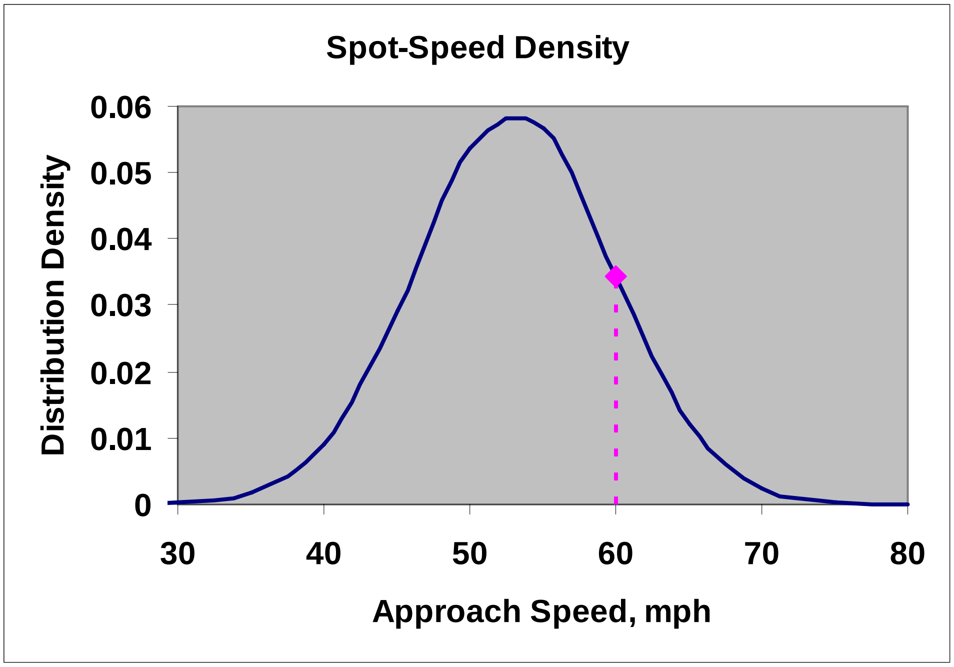
Accurate and relevant data are the key to the design and evaluation of AWEGS. As can be seen from the equation to determine advance detector location, a careful investigation is needed to obtain precise information on the 99th and 85th percentile speeds in addition to the approach gradient. A speed study therefore becomes extremely important.

Spot-Speed Data

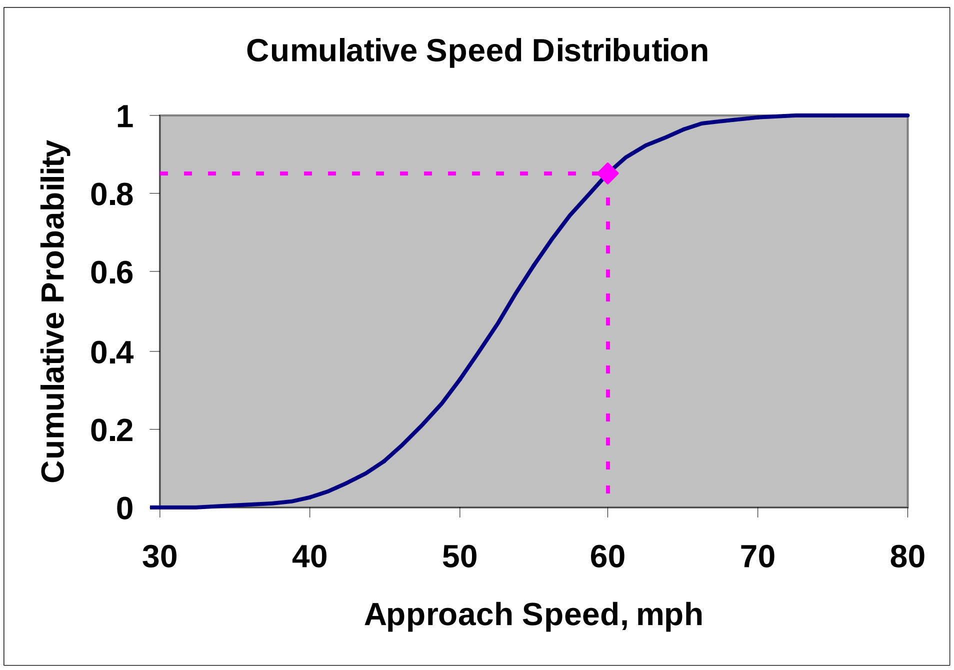
Important inputs to the design of AWEGS systems include the characteristics of traffic flow, including traffic speed, traffic mix, and degree of interruption by adjacent traffic signals. AWEGS design assumes that the arrival traffic is located in Texas, is isolated from adjacent traffic signals, has mixed traffic of cars (and pickups) and trucks, and has free-flowing speeds that are normally distributed. Spot-speed studies for each high-speed approach should consider TxDOT's *Procedures for Establishing Speed Zones* (*10*). Additionally, spot speeds should be recorded only during the green signal display, and the sample station should be located approximately 1000 feet in advance of the signalized intersection.

Data Analysis

An example distribution of spot speeds for a high-speed rural highway is shown in Figure 16a for a mean (50th percentile) speed of 53 mph and an 85th percentile speed of 60 mph. Note that 15 percent of the traffic will be traveling at speeds exceeding the 85th percentile speed. Thus some higher-speed drivers may find stopping on red difficult unless warned in advance. Spot-speed data should provide the following speed results for each approach:



a. Distribution Density of Approach Spot Speeds.



b. Cumulative Distribution of Approach Spot Speeds.

Figure 16. High-Speed Traffic Not Covered by Typical Dilemma Zone Detection Layouts.

Eastbound TX 16 at FM 475:

1. 85th percentile speed: $V_{85\%}$ = 60 mph.
2. 50th percentile speed: $V_{50\%}$ = 53 mph.
3. std. dev. of speed: σ = 7 mph.

Microsoft Excel makes it extremely easy to calculate the percentile values as well as the average and standard deviation from the spot-speed data collected. The Nth percentile can be calculated in Excel by using the function "=*percentile (array,N),*" where N is the percentile desired (e.g., 15th, 50th, or 85th) and array is the selection of all the spot-speed observations. For calculating average, the function *"=average (array)"* and, for the standard deviation, the function *"=stdev (array)"* is to be used.

Existing Dilemma Zone Detection Layout

The existing detector layout for each high-speed approach should be accurately measured. Record all detector locations in feet from the leading edge of the loop to the stopline. Multiple-loop designs may include as many as three to five advance detectors. Nader's guide identifies only two or three dilemma zone detectors with uniform spacing between them, as noted in Table 1. Stop-line queue detection may also be provided. The existing detector layout and related phase timings need to be assessed:

1. Record and evaluate the existing dilemma zone detectors for each approach:

TxDOT Dilemma Zone Detector	Distance to Stopline, Feet	Head-to-Head Spacing, Feet
CDA 1	475	---
CDA 2	375	100
CDA 3	275	100

Example

2. Are the detectors uniformly spaced? (Nader's guide—yes.) Yes
3. Is this a Nader's guide detector layout? Yes
4. If so, for what design speed? 60 mph
5. Record the passage gap recommended by Nader's guide. 1.4 seconds
6. Record the minimum passage gap recorded in Table 1 for Nader's guide. 1.5 seconds
7. Record the passage gap set in the controller for this phase. 2.0 seconds
8. If Nader's guide, is passage gap set OK? Yes = #7 ≥ #6 Yes

Traffic Signal Controller Programming

The AWEGS algorithm requires some signal controller parameters to predict the operation of the traffic signal controller. These include main-street phase numbers, phasing sequence (ring structure), phase minimums, phase maximums, and passage times. AWEGS functions under the assumption that Nader's guidelines (6) are used in the placement of the dilemma zone detectors. Nader's guidelines also recommend the passage times to be used. TTI researchers have recommended some modifications in the passage times. These modifications are based on the probability of premature gap-outs for passage gaps by detector design. Figure 17 illustrates the probability of premature gap-outs for passage gaps by detector design for no speed change, i.e., uniform detector layout. It is illustrated in Figure 17 for approach speeds of 45 mph and 50 mph that a passage gap of about 2.8 seconds is needed and for higher speeds that a passage gap of about 1.6 seconds is necessary to avoid premature gap-outs. However, when approach speeds differ from design speeds, these probabilities change. This implies that attention should be given to the actual approach speeds and engineering judgment applied in the selection of passage gaps. However, a large passage time should not be used. A large passage time will prevent the phase from gapping out, resulting in frequent max-outs, which is not desirable.

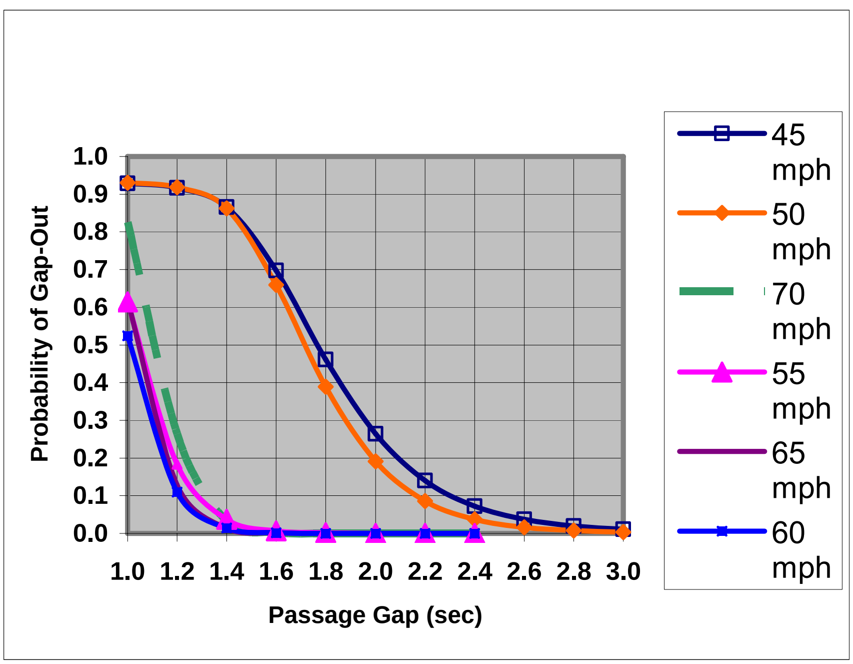


Figure 17. Probability of Premature Gap-Out for Passage Gaps for No Speed Error.

Table 4 illustrates the location of the detectors and the passage times recommended by Nader's guidelines (6) as well as TTI recommended passage times.

Table 4. Nader's Guide on Detector Installation with TTI's Recommended Passage Times.

Approach Speed, mph	Distance from Head of Detector to Stopline at Intersection, Feet			Stopline Area Detector[a], Feet	Passage Gap[a], Seconds	TTI Rec. Passage Gap[b], Seconds
	CDA 1	CDA 2	CDA 3			
45	330	210	---	6 x 40	2.0	2.8
50	350	220	---	6 x 40	2.0	2.8
55	415	320	225	6 x 40	1.2	1.6
60	475	375	275	6 x 40	1.4	1.5
65	540	430	320	6 x 40	1.2	1.6
70	600	475	350	6 x 40	1.2	1.7

[a] Nader's guide
[b] Minimum recommended gap

Figure 17 illustrates the need for the proper selection of passage times. It is crucial that appropriate passage times be used, as it will have an impact on AWEGS operations. AWEGS works on the assumption that Nader's detector guidelines are followed for installation of detectors, and appropriate passage times are used to ensure safe and efficient intersection operations. It is also crucial that the engineers and technicians verify the location of the dilemma zone detectors and ensure that the correct controller settings are coded in AWEGS. To predict the controller operations, users will have to make the following minor changes to the detector delay.

Detector Delay

It is necessary to program a delay of 1 to 5 seconds on the arterial left-turn phases and side-street phases in the controller. Note that this delay is programmed in the signal controller and not on the detector amplifier. This delay, which is only effective during red, is necessary for two reasons. A delay placed in the controller will provide vehicle presence data to the AWEGS algorithm before the signal controller detects it. Hence, AWEGS has an opportunity to respond to the call on the side street or arterial left turn by flashing the beacons if necessary.

Secondly, AWEGS may sometimes start flashing the beacons because of false actuations. These false actuations occur when arterial left-turn vehicles actuate the side-street detector or when left-turn vehicles from the side street actuate the arterial left-turn detector. Placing a delay on these detectors minimizes the occurrences of the traffic signal controller and AWEGS responding unnecessarily to these false calls.

Table 3 illustrates the detector delays recommended in the signal controller to use AWEGS on Phase 2 and Phase 6 at an example intersection. Delays recommended in the table should be programmed *in the traffic signal controller*. The algorithm is monitoring the detector status on the detector panel. Thus, AWEGS detects the presence of the vehicle as soon as the vehicle actuates the detector. However, by introducing the delay in the controller, the controller does not detect these vehicles until the delay has expired. This time lag permits AWEGS to function appropriately by flashing the beacons and provide warning if necessary. This time lag also prevents the controller from reacting to unnecessary actuations like permitted arterial left turns that turn on a green ball, false actuations, and right turns on red. Reduction in the controller reacting to these unnecessary actuations improves intersection operations as well as AWEGS performance.

Table 5. Recommended Detector Delays for a Typical Intersection.

Phase Number	Movement Type	Condition	Delay, Seconds	Purpose
1 and 5	Arterial left—protected	If no false actuations from side-street lefts	1	To have advance warning before controller
		If side-street lefts actuate arterial left-turn detectors	3–4	To filter false calls and have advance warning before controller
	Arterial left—protected-permitted	None	3–4	To filter permitted arterial left-turn traffic, to filter false calls from side street and have advance warning before controller
3 and 7	Side-street left	If no false actuations from arterial lefts	1	To have advance warning before controller
		If arterial lefts actuate side-street left-turn detectors	3–4	To filter false calls
4 and 8	Side-street through	If side-street right-turn traffic actuates the detectors	7–8	To filter right-turn-on-red vehicles

AWEGS Programming

The AWEGS algorithm requires some input parameters for the system to start functioning. These parameters include signal controller data, intersection detector location data, advance detector location data, and the location of AWEGS signs from the stop bar. The signal controller data include phase numbers, phasing sequence (ring structure), phase minimums, phase maximums, and passage times. Figure 18 illustrates the AWEGS application display screen. More details of the programming of the AWEGS software is illustrated in Appendix B.

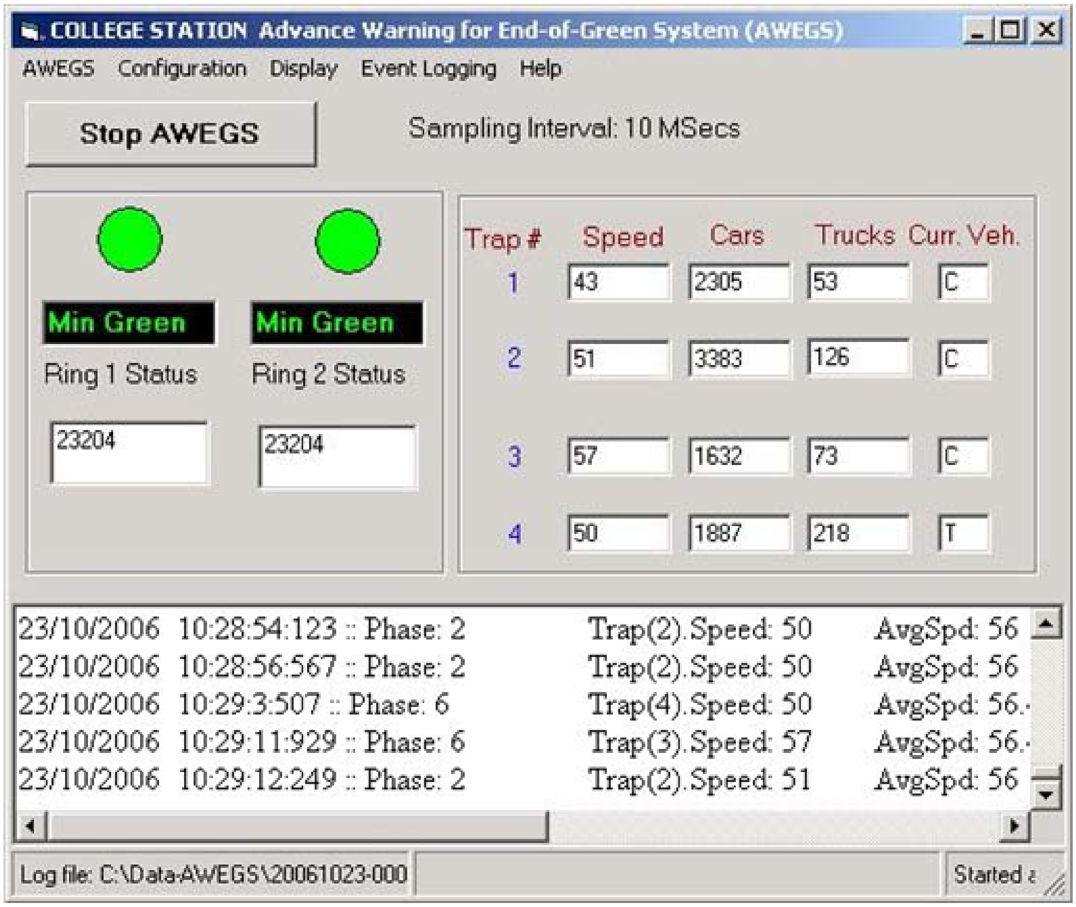


Figure 18. AWEGS Application Display Screen.

MAINTENANCE GUIDELINES

Maintenance of various components needs to be given careful attention to properly operate AWEGS. These components are listed below.

Beacons and Signs

The alignment of W3-4 signs and LED beacons should be maintained as specified. They should always target the road at driver eye height near the advance detectors. Signs and beacons can rotate due to high winds and lose their orientation if they are not tightened properly. The beacons should also be verified to ensure that the LED beacons continue to provide the necessary illumination and provide acceptable flashing operation.

W3-4 sign assemblies (signs and beacons) should also be frequently checked for damage due to vandalism. These W3-4 sign assemblies have an important function by providing motorists with critical information about signal indication changes. Hence, efforts should be made to ensure continuous functionality of these assemblies.

The technicians or engineers can easily identify if AWEGS is operating in its back up mode by observing the beacons flashing for a few cycles. If AWEGS was implemented with a stutter flash, AWEGS operation is normal when the beacons are having a stutter flash. If the beacons are having a normal flash, it would mean that AWEGS is operating in the back up mode. However, if AWEGS was implemented with a normal flash, the technician or the engineer may have to observe more than one cycle to see if the beacons start flashing before the onset of yellow. If he beacons start flashing before the onset of yellow, AWEGS is operating is properly. However if the beacons are always starting at the onset of yellow in the traffic signal indication, AWEGS may be in its back up mode.

Traffic Signal Controller Data

It is essential that AWEGS uses the data residing in the traffic signal controller. Any change made in the signal controller settings also needs to be made in the AWEGS database. Failure to do so could result in AWEGS not performing properly. The signal controller data to be verified include phasing sequence (ring structure and/or alternate sequence), phase minimums, phase maximums, passage times, and phase detector delays.

Detectors

Properly functioning detectors are critical for AWEGS functionality. These include the intersection detectors (including dilemma zone detectors) as well as the advance detectors. Regular inspection for the functionality of these detectors is essential. Detector amplifiers should also be checked for their settings and confirmed in the AWEGS database

APPENDIX REFERENCES

1 .. Messer, C.J., S.R. Sunkari, H.A. Charara, and R.T. Parker. *Development of Advance Warning Systems for End-of-Green Phase at High Speed Traffic Signals.* Report 4260-4, Texas Transportation Institute, College Station, Texas, September 2003.

2 *Manual on Uniform Traffic Control Devices*. U.S. Department of Transportation, Washington, D.C., December 2000.

3 *Sign Crew Field Book.* Second Edition, Traffic Operations Division, Texas Department of Transportation, Austin, Texas, April 1998.

4 *Texas Manual on Uniform Traffic Control Devices*. Texas Department of Transportation, Austin, Texas, 2003.

5 Messer, C.J., S.R. Sunkari, H.A. Charara, and R.T. Parker. *Design and Installation Guidelines for Advance Warning Systems for End-of-Green Phase at High Speed Traffic Signals.* Report 4260-2, Texas Transportation Institute, College Station, Texas, September 2003.

6 "Detector Chapter/Applications Manual" (draft). Traffic Operations Division, Traffic Management Section, Texas Department of Transportation, Austin, Texas, circa 1996.

7 Sunkari, S.R., C.J. Messer, H.A. Charara, and R.T. Parker. *Signal Technician's Installation and Maintenance Manual for Advance Warning for End-of-Green Phase at High Speed Traffic Signals.* Report 4260-3, Texas Transportation Institute, College Station, Texas, September 2003.

8 Sunkari, S.R., R.T. Parker, H.A. Charara, T.A. Palekar, and D.R. Middleton. *Evaluation of Cost-Effective Technologies for Advance Detection.* Report 5002-1, Texas Transportation Institute, College Station, Texas, September 2005.

9 Retting, R.A., A.F. Williams, and M.A. Greene. "Red-Light-Running and Sensible Countermeasures." *Transportation Research Record 1640*, Transportation Research Board, National Research Council, Washington, D.C., 1998.

10 *Procedures for Establishing Speed Zones*. Texas Department of Transportation, Austin, Texas, August 2000.

APPENDIX A – INPUT OUTPUT CHANNEL DETAILS

Input Ports - Intersection with One Lane Approaches

AWEGS Digital I/O Wiring Map for First NI Digital IO Card 6527

Input Port 0

Channel 0 - **47**	Ring 1 - Bit A
Channel 1 - **45**	Ring 1 - Bit B
Channel 2 - **43**	Ring 1 - Bit C
Channel 3 - **41**	Ring 2 - Bit A
Channel 4 - **39**	Ring 2 - Bit B
Channel 5 - **37**	Ring 2 - Bit C
Channel 6 - **35**	Main Phase 1 – Phase On
Channel 7 - **33**	Main Phase 2 – Phase On

Input Port 1

Channel 0 - **31**	Phase 1 – Stop-bar Detector
Channel 1 - **29**	Phase 2 - Stop-bar Detector
Channel 2 - **27**	Phase 3 - Stop-bar Detector
Channel 3 - **25**	Phase 4 - Stop-bar Detector
Channel 4 - **23**	Phase 5 - Stop-bar Detector
Channel 5 - **21**	Phase 6 - Stop-bar Detector
Channel 6 - **19**	Phase 7 - Stop-bar Detector
Channel 7 - **17**	Phase 8 - Stop-bar Detector

Input Port 2

Channel 0 - **15**	ADA – 1	Main Phase 1
Channel 1 - **13**	BDA – 1	Main Phase 1
Channel 2 - **11**	ADA – 2	Main Phase 2
Channel 3 - **9**	BDA – 2	Main Phase 2
Channel 4 - **7**	Main Phase 1 – CDA	
Channel 5 - **5**	Main Phase 2 - CDA	
Channel 6 - **3**		
Channel 7 - **1**		

Main Phase 1 = Main Phase with Number <= 4
Main Phase 2 = Main Phase with Number > 4
Every ADA and BDA is a speed trap. ADA is the leading detector in the trap.

Output Ports - Intersection with One Lane Approaches

AWEGS Digital I/O Wiring Map for First NI Digital IO Card 6527

Output Port 3

Channel 0 - **47**	Main Phase 1 - Flasher – Beacon 1
Channel 1 - **45**	Main Phase 1 - Flasher – Beacon 2
Channel 2 - **43**	Main Phase 2 - Flasher – Beacon 1
Channel 3 - **41**	Main Phase 2 - Flasher – Beacon 2
Channel 4 - **39**	
Channel 5 - **37**	
Channel 6 - **35**	
Channel 7 - **33**	

Output Port 4

Channel 0 - **31**	
Channel 1 - **29**	Main Phase 1 Hold
Channel 2 - **27**	
Channel 3 - **25**	
Channel 4 - **23**	
Channel 5 - **21**	Main Phase 2 Hold
Channel 6 - **19**	
Channel 7 - **17**	

Output Port 5

Channel 0 - **15**	System Heart Beat
Channel 1 - **13**	
Channel 2 - **11**	
Channel 3 - **9**	
Channel 4 - **7**	
Channel 5 - **5**	
Channel 6 - **3**	
Channel 7 - **1**	

Input Ports - Intersection with Two Lane Approaches

AWEGS Digital I/O Wiring Map for First NI Digital IO Card 6527

Input Port 0

Channel 0 - **47**	Ring 1 - Bit A
Channel 1 - **45**	Ring 1 - Bit B
Channel 2 - **43**	Ring 1 - Bit C
Channel 3 - **41**	Ring 2 - Bit A
Channel 4 - **39**	Ring 2 - Bit B
Channel 5 - **37**	Ring 2 - Bit C
Channel 6 - **35**	Main Phase 1 – Phase On
Channel 7 - **33**	Main Phase 2 – Phase On

Input Port 1

Channel 0 - **31**	Phase 1 – Stop-bar Detector
Channel 1 - **29**	Phase 2 - Stop-bar Detector
Channel 2 - **27**	Phase 3 - Stop-bar Detector
Channel 3 - **25**	Phase 4 - Stop-bar Detector
Channel 4 - **23**	Phase 5 - Stop-bar Detector
Channel 5 - **21**	Phase 6 - Stop-bar Detector
Channel 6 - **19**	Phase 7 - Stop-bar Detector
Channel 7 - **17**	Phase 8 - Stop-bar Detector

Input Port 2

Channel 0 - **15**	ADA – 1	Main Phase 1 Left Lane
Channel 1 - **13**	BDA – 1	Main Phase 1 Left Lane
Channel 2 - **11**	ADA – 2	Main Phase 1 Right Lane
Channel 3 - **9**	BDA – 2	Main Phase 1 Right Lane
Channel 4 - **7**	ADA – 3	Main Phase 2 Left Lane
Channel 5 - **5**	BDA – 3	Main Phase 2 Left Lane
Channel 6 - **3**	ADA – 4	Main Phase 2 Right Lane
Channel 7 - **1**	BDA – 4	Main Phase 2 Right Lane

Main Phase 1 = Main Phase with Number <= 4
Main Phase 2 = Main Phase with Number > 4
Every ADA and BDA is a speed trap. ADA is the leading detector in the trap.

AWEGS Digital I/O Wiring Map for Second NI Digital IO Card 6527

Input Port 0

Channel 0 - **47** Main Phase 1 - CDA
Channel 1 - **45** Main Phase 2 - CDA
Channel 2 - **43**
Channel 3 - **41**
Channel 4 - **39**
Channel 5 - **37**
Channel 6 - **35**
Channel 7 - **33**

Input Port 1

Channel 0 - **31**
Channel 1 - **29**
Channel 2 - **27**
Channel 3 - **25**
Channel 4 - **23**
Channel 5 - **21**
Channel 6 - **19**
Channel 7 - **17**

Input Port 2

Channel 0 - **15**
Channel 1 - **13**
Channel 2 - **11**
Channel 3 - **9**
Channel 4 - **7**
Channel 5 - **5**
Channel 6 - **3**
Channel 7 - **1**

Output Ports - Intersection with Two Lane Approaches

AWEGS Digital I/O Wiring Map for First NI Digital IO Card 6527

Output Port 3

Channel 0 - **47**	Main Phase 1 - Flasher – Beacon 1
Channel 1 - **45**	Main Phase 1 - Flasher – Beacon 2
Channel 2 - **43**	Main Phase 2 - Flasher – Beacon 1
Channel 3 - **41**	Main Phase 2 - Flasher – Beacon 2
Channel 4 - **39**	
Channel 5 - **37**	
Channel 6 - **35**	
Channel 7 - **33**	

Output Port 4

Channel 0 - **31**	
Channel 1 - **29**	Main Phase 1 Hold
Channel 2 - **27**	
Channel 3 - **25**	
Channel 4 - **23**	
Channel 5 - **21**	Main Phase 2 Hold
Channel 6 - **19**	
Channel 7 - **17**	

Output Port 5

Channel 0 - **15**	System Heart Beat
Channel 1 - **13**	
Channel 2 - **11**	
Channel 3 - **9**	
Channel 4 - **7**	
Channel 5 - **5**	
Channel 6 - **3**	
Channel 7 - **1**	

APPENDIX B – AWEGS PROGRAMMING SCREENS

AWEGS Configuration

The AWEGS system has 4 drop down menus: AWEGS Menu, Configuration Menu, Display Menu, and Help Menu. Each menu includes a number of options that gives the user access either to data entry screens or turning on/off selections.

AWEGS Menu

The AWEGS drop down menu has the following options:

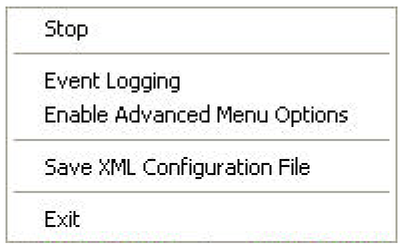


Figure 19. Options in AWEGS Menu.

- **Stop**: The stop option allows the user to stop the AWEGS system. Once stopped, the Stop option is changed to "Start" and the user can select it to restart the AWEGS system.
- **Event Logging**: The Event Logging option opens a new window (Figure 20) that includes a list of the seven data logging events provided by AWEGS. The user can select/deselect each option by checking/un-checking the Check Box next to the option in the list. The seven data logging options provided by AWEGS include:
    - General Events (.Ada Files): This option enables the user to log into a daily log file, with ".Ada" extension, the stop-bar detector actuations, dilemma zone detector actuations, advance trap detector actuations, and traffic signal system events like phase status.
    - Detector Failure Events (.DetFail Files): This option logs into a daily log file, with ".DetFail" extension, failures of any trap detector, dilemma zone detector, or stop-bar detectors.
    - Flashing Events (.Flash Files) : This option logs into a daily log file, with ".Flash" extension, a record of every time AWEGS makes a decision to flash the beacons to warn incoming upstream traffic.

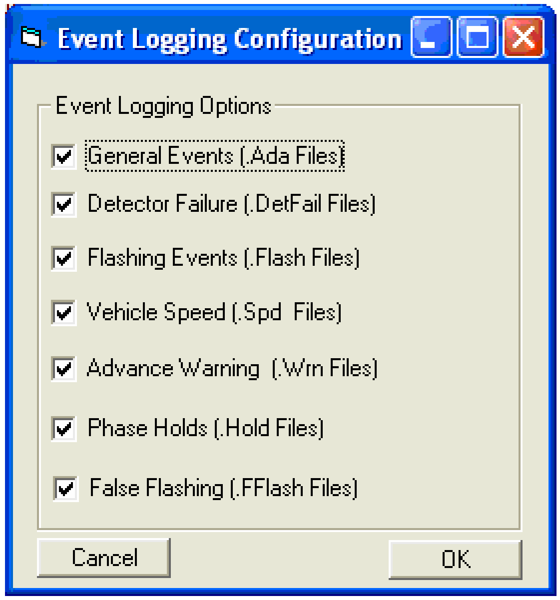


Figure 20. Event Logging Menu.

- Vehicle Speed Events (.Spd Files): This option logs into a daily log file, with ".Spd" extension, the speed of every vehicle detected by AWEGS advance trap detectors.
- Advance Warning Events (.Wrn Files): This option logs into a daily log file, with ".Wrn" extension, the duration of advance warning AWEGS provided to motorists before the end of each green phase on main street.
- Main-Street Phase Hold Events (.Hold Files): This option logs into a daily log file, with ".Hold" extension, the duration of each phase hold placed by the AWEGS system.
- False Flashing Events (.FFlash Files): This option logs into a daily log file, with ".FFlash" extension, each false flash decision made by AWEGS.

- **Enable Advanced Menu Options**: This option enables some of the advanced data entry configuration screens that are by default disabled when AWEGS starts.
- **Save XML Configuration File**: This option enables the user to save any changes he makes to the AWEGS configuration into the AWEGS.XML configuration file. Any time the user makes any changes to the AWEGS configuration, he must select this option to save the changes to the configuration file so that AWEGS will remember these changes

when stopped and started again. Otherwise, the changes are lost when AWEGS is stopped and the user must reenter them again.

- **Exit**: This option enables the user to terminate the AWEGS system.

Configuration Menu

The Configuration menu (Figure 21) includes the following options:

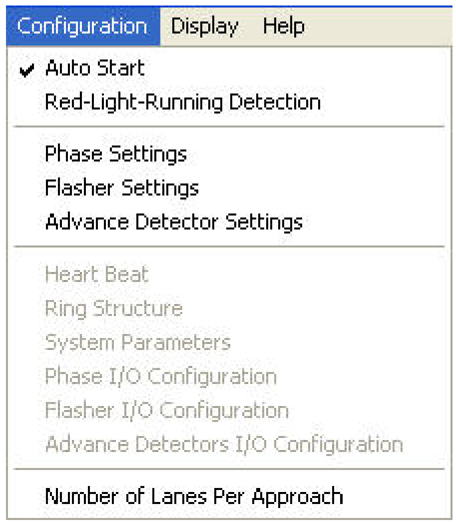


Figure 21. Configuration Menu.

- **Auto Start**: Selecting this option will enable the AWEGS system to run automatically when AWEGS is started. Otherwise, the user has to select the "Start" option from the AWEGS menu and start the system manually. This option is included and must be selected when the system is running in the field so that AWEGS will start automatically any time the industrial PC is booted due to power failure in the field. The check-mark before the "Auto Start" option in the menu indicates it is currently selected. The check-mark is turned on/off by selecting/deselecting the menu option again.
- **Red-Light-Running Detection**: Similar to the "Auto Start" option, the "Red-Light Running Detection" option is turned on/off by selecting/deselecting the option again. This option enables the user to turn on the logging into a daily log file of ".vda" extension, red-light running events for further evaluation by the user. However, before turning this option on by selecting it, the user must install video cameras properly at the

intersection and define the red-light running detection zones properly in front of the stop-bar for main street phases.

- **Phase Settings**: This option provides the user with a new window called "Phase Settings" (Figure 22) where the user can enter the main street phase data required by AWEGS. The phase data required by AWEGS include: main street phases minimum green in seconds, MAX # 1 in seconds, Passage time in seconds, "C1 to SB Dist" i.e., the distance from the leading edge of the first dilemma zone detector (furthest from the stop-bar) to the stop-bar in feet, "C2 to SB Dist" i.e., the distance from the leading edge of the middle dilemma zone detector to the stop-bar in feet, "C3 to SB Dist" i.e., the distance from the leading edge of the third dilemma zone detector (Closest to the stop-bar) to the stop-bar in feet, average speed on main street approaches, 85th percentile speed on main street approaches, and detector delay required by AWEGS and entered in the controller for each minor street or arterial left turn stop-bar detector. The user must also specify whether a main street phases by selecting the proper check-boxes in the "Main Phase" check-boxes row, direction of the main street phase from the pull down combo boxes in the "Direction" row, whether he wants to display the main street phases in the intersection display by checking the proper check-box in the "Phase On" row, the phases that AWEGS is monitoring either their detector input or phase check input in the "Phase Check" row, the phases that has "Memory On" turned on in the controller, the phases that are considered minor street phases in the "Minor Phase" row, the arterial left phases from the "Art. Left Phase" row, and the proper check-boxes in the "Lagging Left" row to indicate whether an arterial left turn phase is leading or lagging. Once the user finishes entering the required information in the "Phase Settings" window, he must click the "Update Phase Settings" button to save the entered information into AWEGS memory.

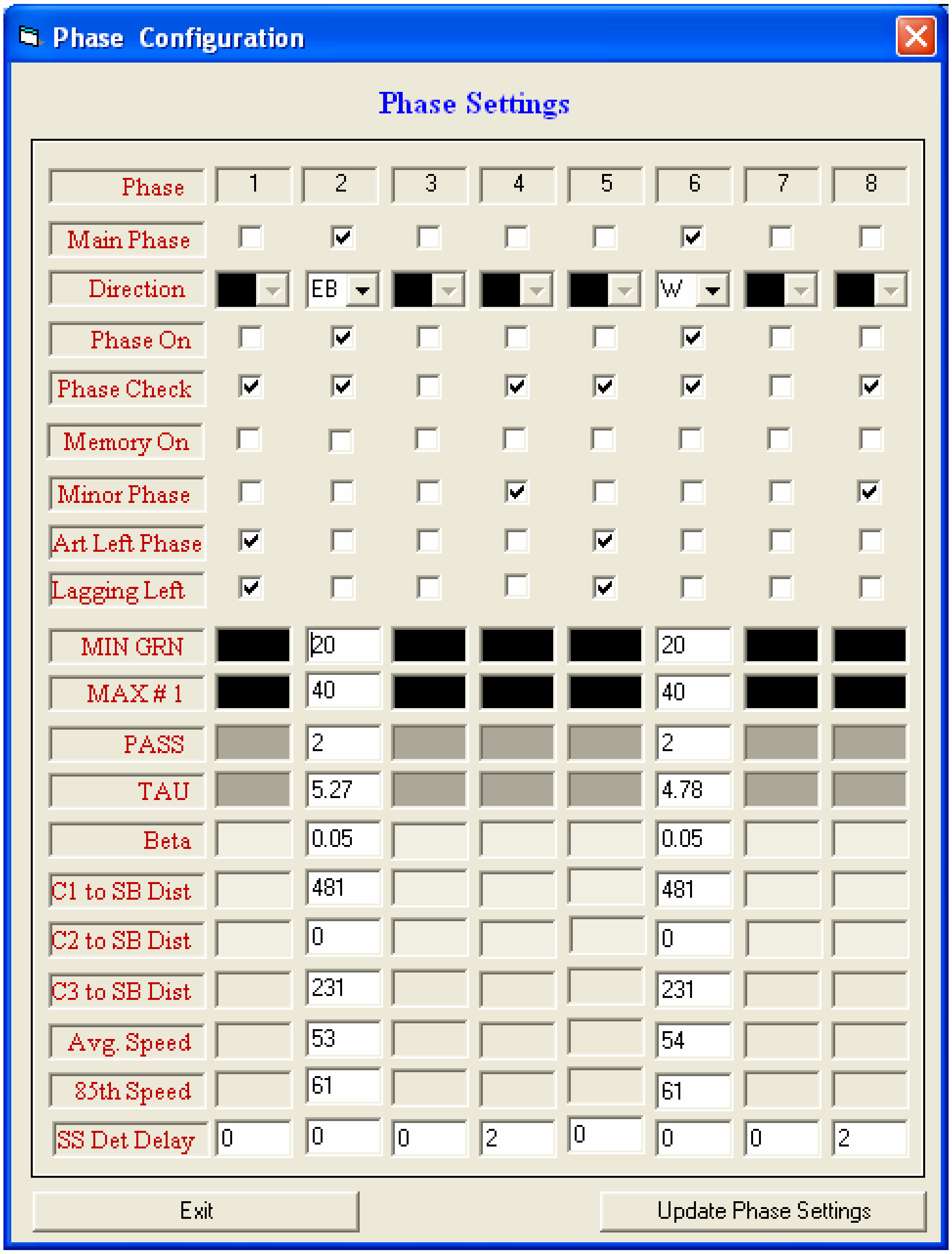


Figure 22. Phase Configuration Screen

- **Flasher Settings**: This option provides the user with a new window called "Flashing Mode Configuration" (Figure 23) where he can select the Flashing Mode (Stutter or Normal), the duration of the ON interval of the flashing beacons (Half Cycle ON Interval), and the duration of the completely OFF interval during which both beacons on the W3-4 warning signs will be off (Half Cycle OFF Interval). In case the user selected the Stutter flash mode, he needs to enter the duration for the ON and OFF portions of each of the three intervals "Interval1", "Interval2", and "Interval3" under the Stutter Flash Parameters section in the window. The total value of all of the ON and OFF portion of the three intervals should be equal to the value entered for the "Half Cycle ON Interval". By clicking the "OK" button, the new values entered are saved into AWEGS memory. However, if the user wants the values to be remembered by AWEGS for the next time it is stopped and started again, the user must select the "Save XML Configuration File" option under the AWEGS menu to save the new settings into the configuration file.

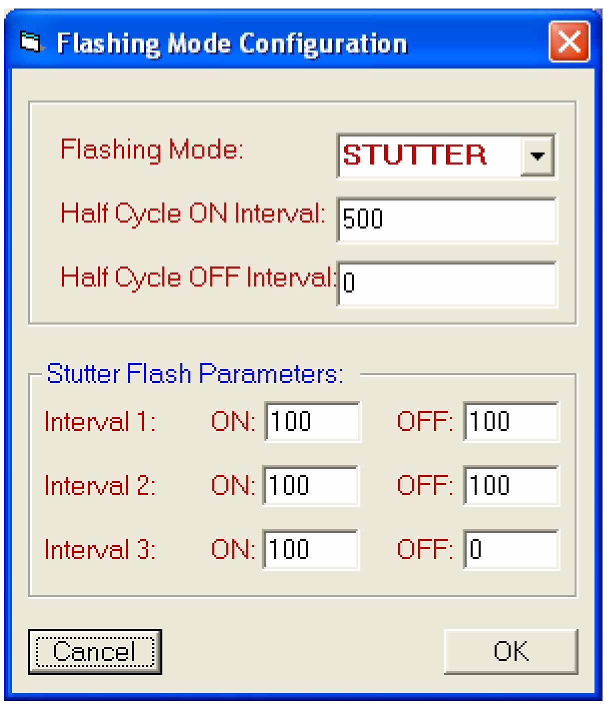


Figure 23. Flashing Mode Configuration Screen.

- **Advance Detector Settings**: This option opens a series of windows that enables the user to enter the information required by AWEGS about the advanced trap detectors, dilemma zone detectors, and video detectors used for verification of red-light running. The detectors are organized by the main street phase they belong to. The first window opened is the "Advance Detector Selection" (Figure 24) that enables the user to select the main street phase the detectors belong to. Once the user select a main street phase from the pull down list, depending on the direction chosen for the main street phase in the "Phase Settings" window, a series of detectors are drawn in the middle section of the "Advanced Detector Selction" showing the advance trap detectors, dilemma zone detectors, and video detectors that belong to that phase. By clicking on each detector in the middle section, a new window called "Advanced Detector Configuration" (Figure 25) is provided to the user when he can the relevant information required by AWEGS for that detector.

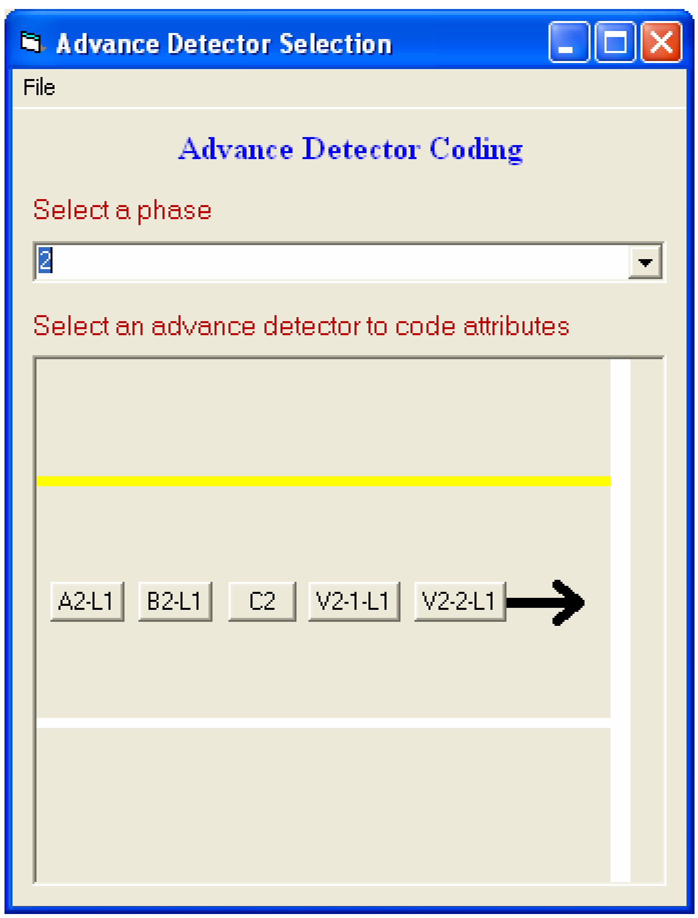


Figure 24. Detector Configuration Selection Screen.

Figure 25 shows the data elements required by AWEGS for each advance detector. The two data elements required include the distance to stop-bar from the leading edge of the advance detector and the distance from the leading edge of the advance detector to the leading edge of the first dilemma zone detector (furthest from the stop-bar) for the given approach. The user must also specify digital I/O channel the advance detector input is feeding into on the digital I/O connector block. If the advance detectors are wired according to the provided standardized configuration files and the standardized digital I/O connector block drawings, the proper digital I/O channel will be already selected for the user. After entering the required information, the user must click the "Update AD" button for the information to be saved into AWEGS memory.

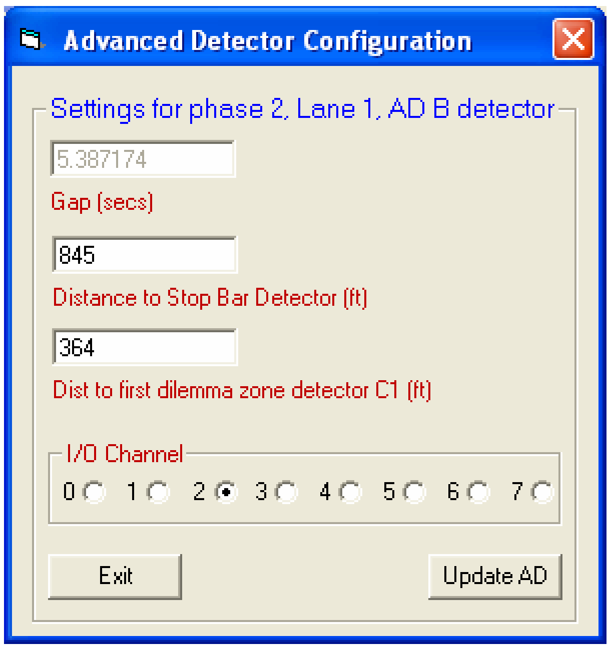


Figure 25. Advance Detector Configuration Screen.

Figure 26 shows the data elements required by AWEGS for the dilemma zone detectors of the selected phase. The passage time (Gap) and the distance of the first dilemma zone detector C1 (furthest from the stop-bar) are shown as they were entered in the "Phase Settings" window by the user. These values cannot be changed in this window. If the user would like to change these values, they can be changed in the "Phase Settings" window. However, the user must specify the digital I/O channel the dilemma zone detectors input is feeding into on the digital I/O connector block. If the dilemma zone detectors input is wired according to the provided standardized configuration files and the standardized digital I/O connector block drawings, the proper digital I/O channel will be already selected for the user. After entering the required information, the user must click the "Update AD" button for the information to be saved into AWEGS memory.

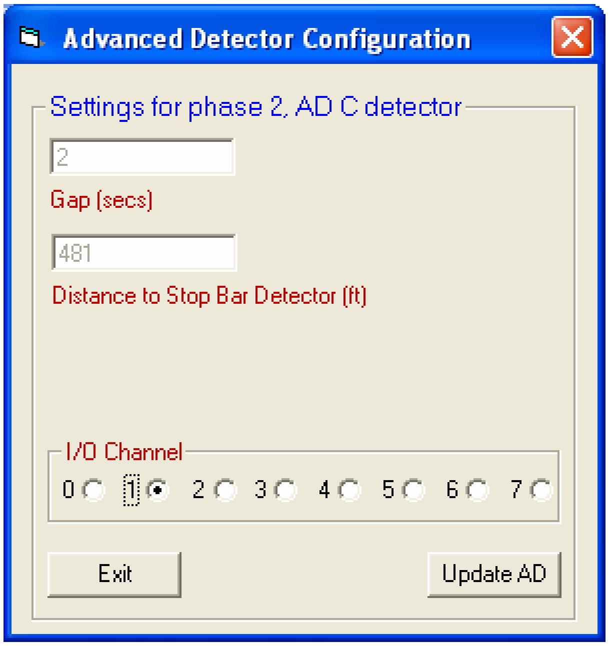


Figure 26. Dilemma Zone Detector Configuration Screen.

Figure 27 shows the data elements required by AWEGS for video detectors setup for logging red-light running events for the selected phase. The only input required for each video detector is the digital I/O channel the detector is connected to on the I/O connector block. If the video detector input is wired according to the provided standardized configuration files and the standardized digital I/O connector block drawings, the proper digital I/O channel will be already selected for the user. After entering the required information, the user must click the "Update AD" button for the information to be saved into AWEGS memory.

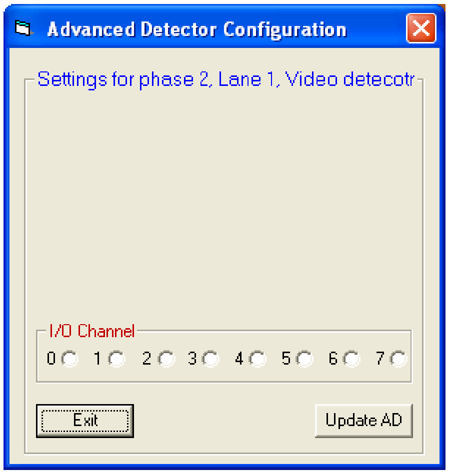


Figure 27. Video Detector Configuration Screen.

- **Heart Beat**: This option opens a new window called "Heart Beat Signal Settings" (Figure 28) which allows the user to configure the digital I/O channel and port settings for the heart beat signal sent from the AWEGS system to the backup flashing panel every second while the AWEGS is up and running. The backup flasher panel is independent of the AWEGS system. The heart beat signal is used by the AWEGS system to indicate to the backup flashing panel that it is up and running fine. The signal is connected to a timer on the backup flashers panel. The timer is reset and start counting down from 30 to 0 every time it receives the heart beat signal from the AWEGS system. If for any reason, the AWEGS system is down or stops sending the heart beat signal, the backup flasher panel takes over once the timer reaches zero. The backup flasher panel provides the minimal warning possible when the AWEGS system is not functioning properly. That is, the backup flasher panel will start flashing the beacons on the advance warning sign from the onset of yellow to the onset of green for main street phases. The data elements required for the configuration of the heart beat signal include the digital I/O device, port, and output channel used to send the signal to the backup flasher panel. If the hear beat signal output is wired according to the provided standardized configuration files and the standardized digital I/O connector block drawings, the proper digital I/O device, port, and channel will be already selected for the user. After entering the required information, the user must click the "OK" button for the information to be saved into AWEGS memory.

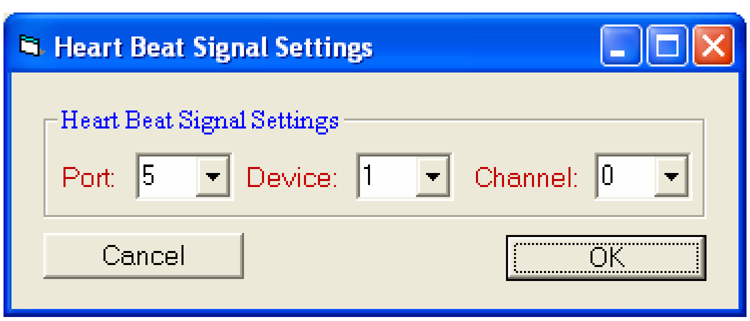


Figure 28. Heart Beat Configuration Screen.

- **Ring Structure**: This option opens a window called "Ring Structure" (Figure 29) that enables the user to define the ring structure for the phases at the intersection. The user can enter for each phase, the concurrent phases, next phase in the phasing sequence, and the ring the phase belongs to. The user can also enter whether the "Simultaneous Gap-Out" feature is turned on or off in the controller. The user must also specify the digital I/O device and port that the ring status bits are connected to on the digital I/O connector block. If the ring status bits inputs are wired according to the provided standardized configuration files and the standardized digital I/O connector block drawings, the proper digital I/O device and port will be already selected for the user. After entering the required information, the user must click the "Update Ring Structure" button for the information to be saved into AWEGS memory.

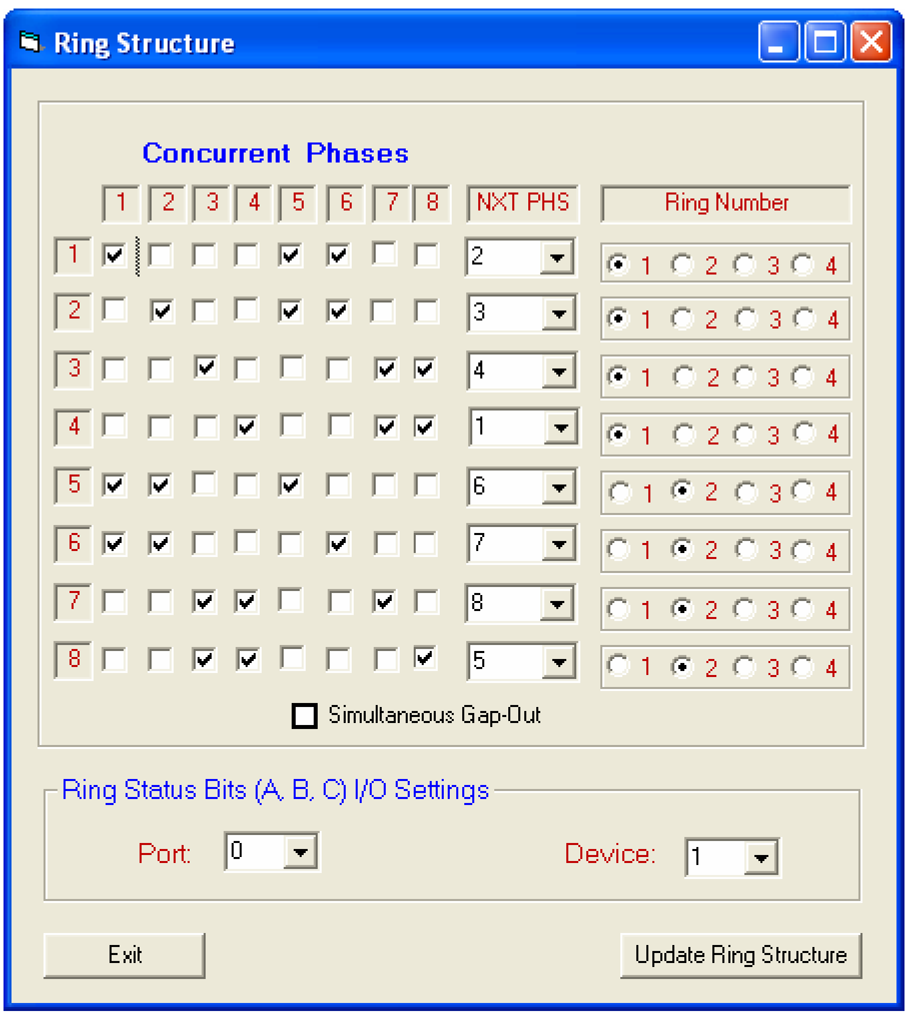


Figure 29. Ring Structure Configuration Screen.

- **System Parameters**: This option provides the user with a new window called "System Parameters" (Figure 30) that enables him to enter data element that are particular to the site and AWEGS system running at the site. These data elements include the name of the city that the intersection belongs to, the names of the roads at the intersection, whether stop-bar detectors are installed at the intersection to allow AWEGS to continue to flash after the onset of green on the main street phases if there is a queue at the approach. Other data elements included in this window that the user can modify include ZDelMax, ProbT, ZDelHold, System Timer, Extra Phase Hold, ADA Logic, BDA Logic, CDA Logic, Phase On Logic, Phase Check Logic, and Ring Bits Logic. The user must not change the values of these data elements as specified in the configuration file. After entering the required information, the user must click the "OK" button for the information to be saved into AWEGS memory.

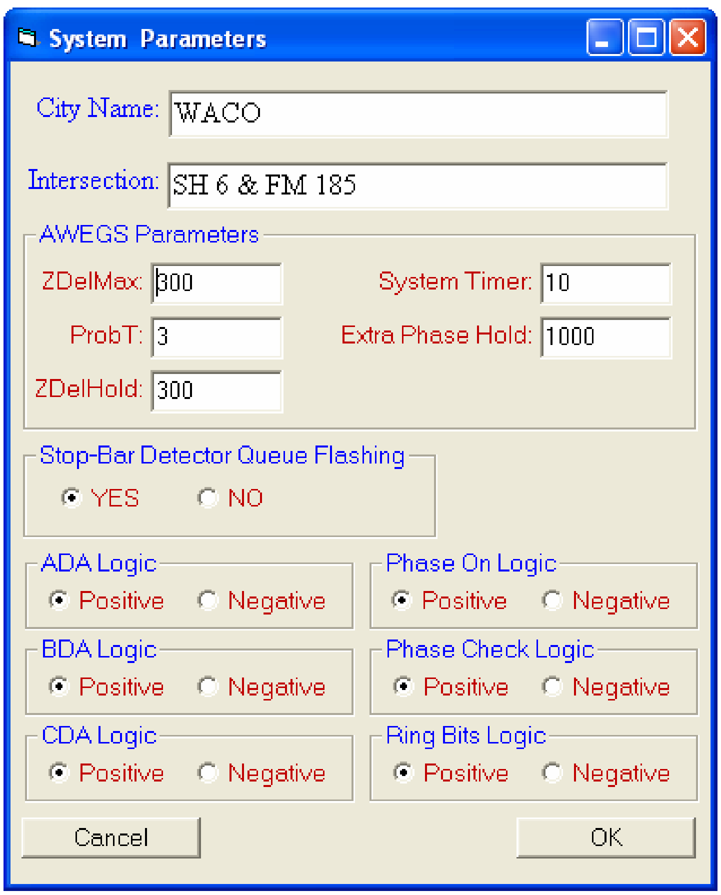


Figure 30. System Parameter Configuration Screen.

- **Phase I/O Configuration**: This option provides the user with a window called "Phase I/O Settings" (Figure 31) where the user can specify the digital I/O channel, port, and device settings for the "Phase On" input, "Phase Check" input, and "Phase Hold" output settings. In specifying the digital I/O channel for phase inputs and outputs, the user must select a phase group, i.e., Phase On, Phase Check, or Phase Hold group, from the "Select Phase Group" pull down list first. Once a phase group is selected, the user then selects an option button that corresponds to the phase he is selecting from the "Phase Number" option buttons group. The AWEGS system will display the selected channel for that phase if it has been entered earlier and the user can change it by selecting an option button that corresponds to the desired channel from the "I/O Channel" option buttons group. After entering the required information, the user must click the "Update Phase Channel Mapping" button for the information to be saved into AWEGS memory. To update the digital I/O device and port information for the phase inputs and outputs, the user can select the proper values from drop down combo boxes and click the "OK" button to save the updated information into AWEGS memory. If the phase inputs and outputs are wired according to the provided standardized configuration files and the standardized digital I/O connector block drawings, the proper digital I/O device, port, and channel will be already selected for the user.

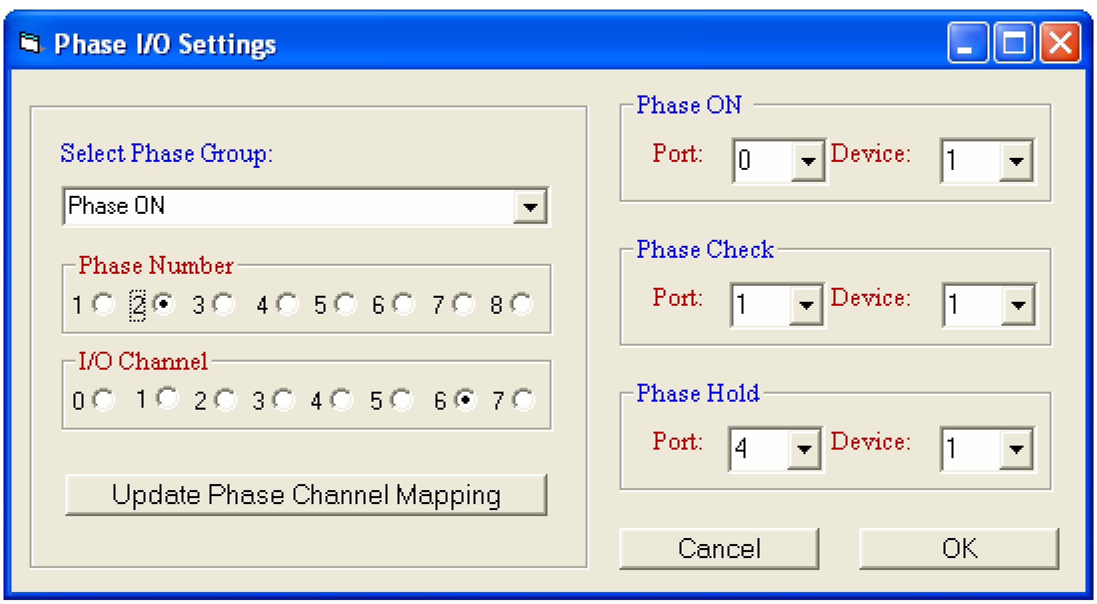


Figure 31. Phase I/O Configuration Screen.

- **Flasher I/O Configuration**: This option provides the user with a window called "Flashing Beacon I/O Settings" (Figure 32) where the user can specify the digital I/O channel, port, and device settings for each flashing beacon on the advance warning signs. Each approach's advance warning sign has a set of two beacon heads that can either flash simultaneously or alternate in flashing. In specifying the digital I/O channel for each phase head, the user must first select a phase number from the "Phases" pull down list. Once a phase is selected, the user then proceeds to select a beacon head from the "Beacon Heads" pull down list. The "I/O Channel" option button group will be enabled and the AWEGS system will display the selected channel for the selected beacon head if it has been entered earlier. The user can proceed with selecting an option button that corresponds to the channel the beacon head output is connected to. The user must click the "Update Flasher" button to save the information to AWEGS memory after updating each beacon-head data. To update the digital I/O device and port information for the beacon heads outputs, the user can select the proper values from the drop down combo boxes and click the "OK" button to save the updated information into AWEGS memory. If the beacon heads outputs are wired according to the provided standardized configuration files and the standardized digital I/O connector block drawings, the proper digital I/O device, port, and channel will be already selected for the user.

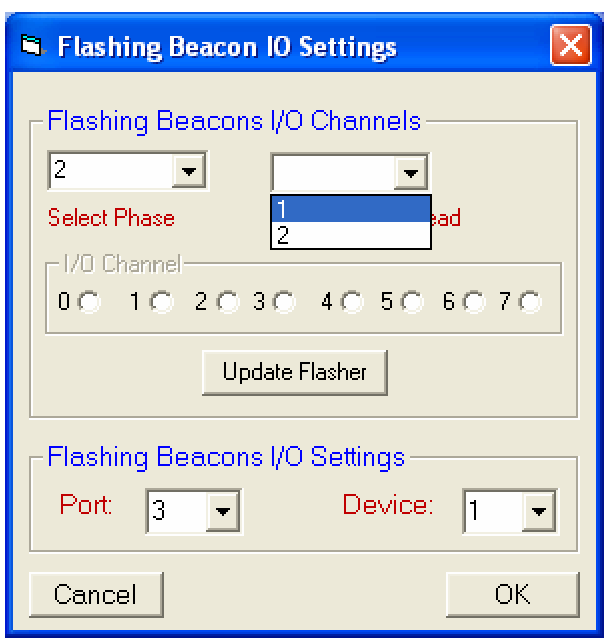


Figure 32. Flasher I/O Configuration Screen.

- **Advance Detector I/O Configuration**: This option provides the user with a new window called "Advanced Detector I/O Settings" (Figure 33) where the user can specify the digital I/O port, and device settings for advanced trap detectors (ADA and BDA), dilemma zone detectors (CDA), stop-bar detectors, and red-light running (RLR) video detectors. To update the digital I/O device and port information for the detector inputs, the user can select the proper values from the drop down combo boxes and click the "OK" button to save the updated information into AWEGS memory. If the beacon heads outputs are wired according to the provided standardized configuration files and the standardized digital I/O connector block drawings, the proper digital I/O device, port, and channel will be already selected for the user.

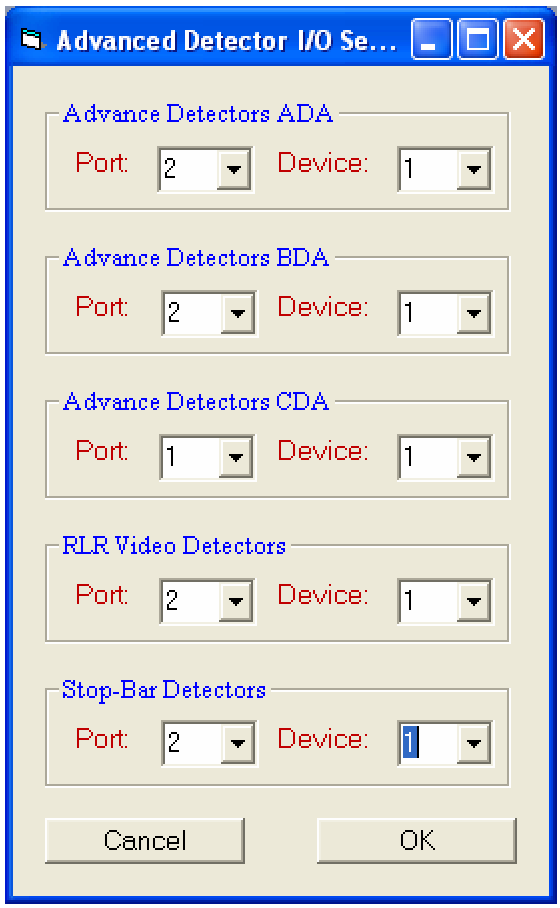


Figure 33. Advance Detector I/O Configuration Screen.

- **Number of Lanes per Approach**: This option enables the user to change the number of lanes per approach from 1 to 2 or vice versa. After changing the number of lanes per approach and saving it to the configuration file, the AWEGS system must be terminated by choosing the "Exit" option from the "AWEGS" menu and restarted again. The proper method to changing the number of lanes per approach is for the user to start the AWEGS system with the two lanes per approach XML configuration file provided by TTI with the software instead of changing a one lane per approach configuration file to a two lanes per approach or vice versa.

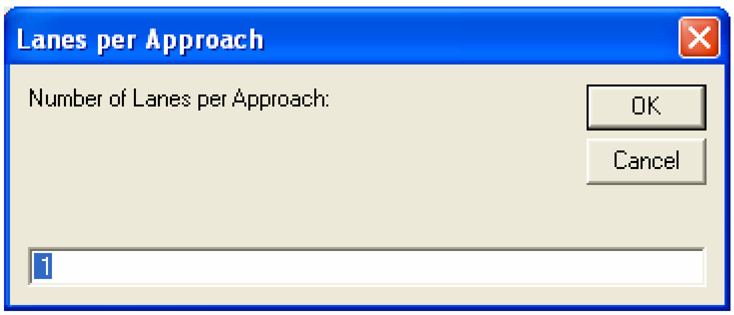


Figure 34. Approach Configuration Screen.

Display Menu

The display menu includes only one option, the Intersection option. Selecting the Intersection option displays a new window that provides the user with a drawing of the AWEGS intersection being monitored and status of the main street phases, advance trap detectors, dilemma zone detectors, stop-bar detectors, ring status, type of the last vehicle detected on each advance trap detector, and duration of the last advance warning provided by AWEGS, and status of the advance warning beacons (On/Off). It also provides information about the decision making process of AWEGS in determining when to start flashing the advance warning beacons.

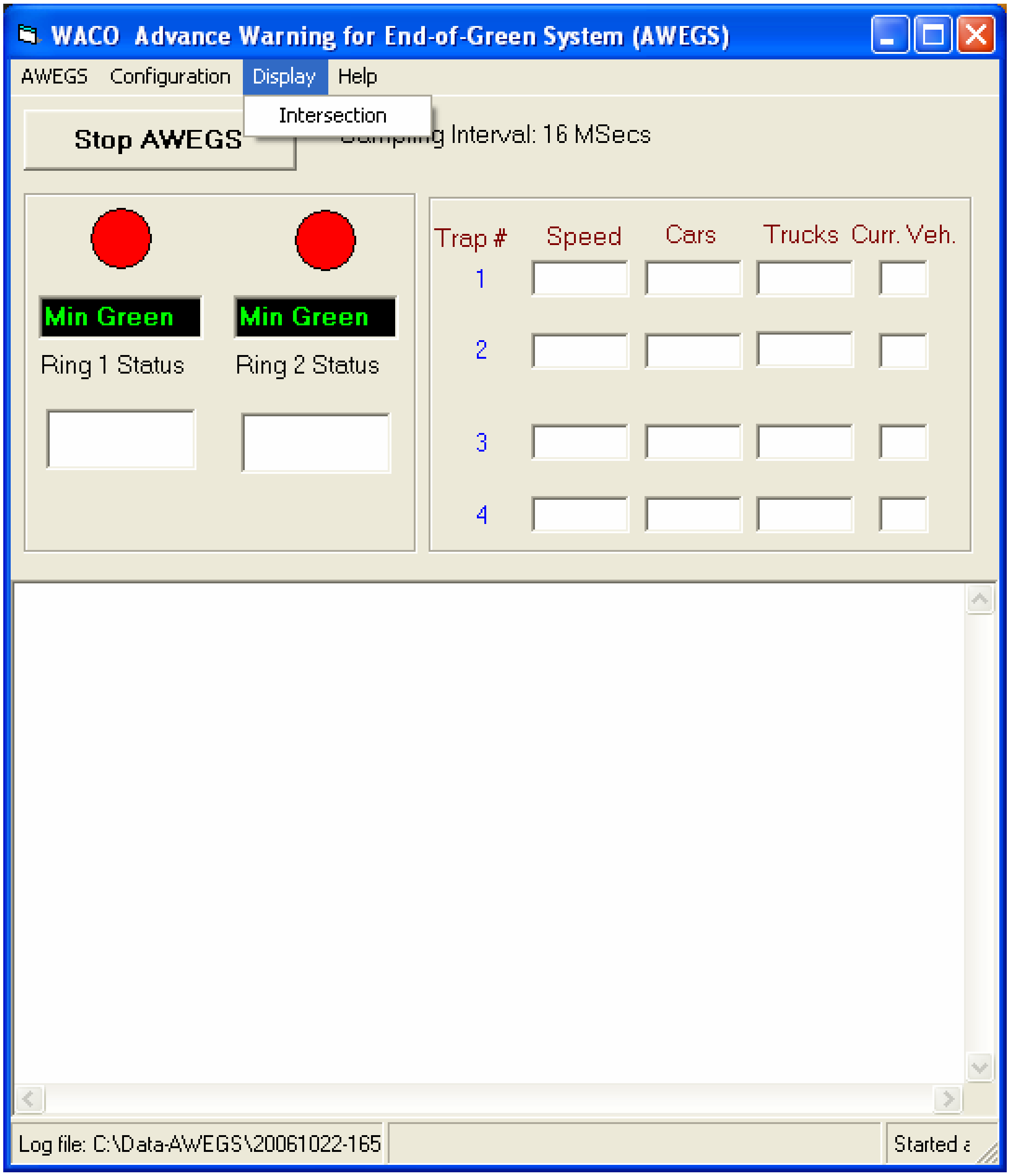


Figure 35. Display Menu.

Help Menu

The Help menu contains only the “About” option that opens a new window (Figure 36), that provides the user with contact phone numbers and e-mail address in case there was a problem with the AWEGS system.

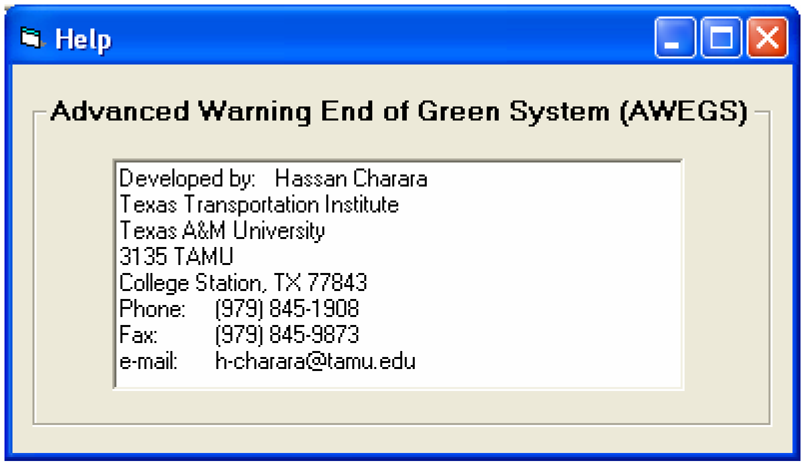


Figure 36. Help Menu.